EXHIBIT 1
Expert Report of Harri Kytomaa

Expert Report of Harri Kytömaa in the Matter of Bates v Tippmann

Exponent®
Engineering P.C.

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Contents

Acronyms and Abbreviations

ASTM	International Association for Testing Materials
CGA	Compressed Gas Association
CO_2	Carbon Dioxide
DOT	Department of Transportation
in.	Inch
lb.	Pound
mm	Millimeter
NFPA	National Fire Protection Association
oz.	Ounce
PRD	Pressure Relief Device
psi	Pound per square inch

Limitations

At the request of Robinson, Bradshaw & Hinson, P.A., Exponent Engineering P.C. (Exponent) conducted an investigation of the fatal explosion that occurred at Neman Bates' residence on February 2, 2015 for the purposes of an ongoing legal matter. The scope of services performed during this investigation may not adequately address the needs of other users of this report, and any re-use of this report or its findings, conclusions, or recommendations presented herein are at the sole risk of the user. The opinions and comments formulated during this assessment are based on observations and information available at the time of the investigation. No guarantee or warranty as to future life or performance of any reviewed condition is expressed or implied.

The findings presented herein are made to a reasonable degree of engineering and scientific certainty. Exponent has made every effort to accurately and completely investigate all areas of concern identified during this investigation. The data and opinions presented in this report are only those finalized at the time of its publication. If new data becomes available or there are perceived omissions or misstatements in this report regarding any aspect of those conditions, we ask that they be brought to our attention as soon as possible so that we have the opportunity to fully address them.

Executive Summary

Exponent Engineering P.C. (Exponent) was retained by Robinson, Bradshaw & Hinson, P.A., to investigate the explosion of a carbon dioxide bottle that occurred in Cherryville, NC at around 6pm on February 2, 2015. The explosion originated from a 9-ounce Tippmann carbon dioxide bottle that was being handled by Mr. Bates in his home. Mr. Bates died as a result of the explosion.

Materials reviewed

Exponent reviewed the reports provided by the Cherryville Police Department. Exponent also reviewed deposition testimony from Holly Beck, Adam William Deck, David Schmitz, Andrew Sheldrick, Michael Shipley, Star Shipley, Douglas Stipanovich, Dennis Tippmann, Shane Zollo, Zen Bates, Gail Selby, William Hearn, and Aaron Stephens as well as relevant DOT and ASTM standards for the design of containers for pressure-liquefied gases.

A full list of the materials reviewed in this matter is provided in Appendix A.

Inspections

Exponent and other parties performed the following laboratory examinations of the paintball equipment (the evidence) owned by the plaintiff at the time of the explosion. The examinations were performed at Exponent's Natick, Massachusetts laboratory on:

- March 17, 2017
- July 11, 2017
- March 29, 2018
- May 8, 2018

Microscopic examination of certain items was performed using both an optical and a scanning electron microscope (SEM). Energy dispersive X-ray spectroscopy (EDS) and computed tomography (CT) X-ray imaging were also performed. Testing of pressure relief device was also performed during the inspections.

Findings and opinions

Based on my education, background, training, experience, testing, analysis, and my review of the relevant materials, I offer the following opinions to a reasonable degree of engineering and scientific certainty. My curriculum vitae, including a list of publications, are provided in Appendix B. If additional information becomes available, I reserve the right to modify or amend these findings:

1. The death of Mr. Bates was caused by an explosion of the Tippman 9 oz. CO_2 bottle.

2. The direct cause of the explosion was the failure of the pressure relief device (PRD) to actuate. The failure of the PRD to actuate allowed the pressure within the Tippman CO_2 bottle to rise sufficiently high to cause the rupture of the bottle.

3. The purpose of the PRD is to burst and relieve pressure during over-pressure events. A properly functioning PRD would have prevented the catastrophic rupture that led to Mr. Bates' death.

4. The high pressure was a consequence of the combined effect of temperature and liquid fill level. High pressures within CO_2 bottles are a common occurrence that can result from elevated temperature, fill level, or both. More than 9 ounces were likely present in the bottle.

5. The direct cause for the PRD malfunction was the presence of a second burst disk within the PRD.

6. The second burst disk within the PRD was installed at the time of manufacture and was not installed by Mr. Bates.

7. The potential for multi-disk assemblies was known to BXD and the Chinese manufacturer, Joxco. The addition of the second disk in the PRD was the result of

inaccurate design drawings, ineffective caliper measurement techniques, and/or insufficient safety auditing and quality control of the manufacturer.

8. It is not possible for a user of a CO_2 bottle to modify the PRD without specialty tooling and there are no indications that Mr. Bates did so. There are no tool marks or other indications on the incident PRD that indicate it had been tampered with prior to the explosion.

9. The subject PRD retaining cap was found to be secured on the incident PRD, which is inconsistent with the cap having been removed and replaced. According to Aaron Stephens, BXD's corporate representative and a specialist hired by BXD for his experience with these products, "*a tool does not exist to cleanly remove the sleeve and people are not going to have the equipment to recrimp*".

10. The PRD installed in the incident Tippmann CO_2 bottle was not compliant with the relevant industry standards and was defective at the time of manufacture, the time of sale and the time of the explosion.

11. The incident Tippmann bottle, including the main valve and PRD, was not compliant with the relevant DOT standards and was defective at the time of manufacture, the time of sale and the time of the explosion.

12. Based on the design of the subject Tippmann CO_2 bottle, if the PRD contains two burst disks, as the subject one did, the PRD will not actuate prior to the catastrophic failure of the bottle.

13. Defendants and their agents knew, or should have known, that a second burst disk in the PRD would raise the relief pressure to beyond the failure pressure of the Tippmann bottle.

14. Dick's Sporting Goods, Tippmann, and Gayston chose to distribute and sell CO_2 bottles designed to meet only the minimum thresholds of safety as determined by the DOT for the transport of pressure-liquefied gases.

15. The contributory cause of the explosion was a lack of quality control in the manufacturing, distribution, and sales system that allowed a defective PRD to be installed in a Tippmann CO_2 bottle that was sold by Dick's Sporting Goods.

16. Because the subject Tippmann bottle did not contain either overfill protection device or overfill indicator to prevent overfilling, the over-pressurization of a bottle is a common and foreseeable condition that should be protected against using a reliable safety device.

Note that this Executive Summary does not contain all of Exponent's technical evaluations, analyses, conclusions, and recommendations. Hence, the main body of this report is at all times the controlling document.

Background

Incident Description

At approximately 6:25pm on February 2, 2015 the Cherryville Police Department responded to a 911 emergency call at 301 Nemans Cove, Cherryville, NC 28021.[1] Mr. Neman Bates was found unconscious and not breathing. He was later transported to the Cleveland Regional Medical Center where he was pronounced deceased shortly after his arrival.

On February 1st, 2015, Mr. Bates had played paintball with a group of friends starting at around 1 to 2 PM until 4 to 5 PM.[2,3,4] After the paintball game, Mr. Bates refilled his CO_2 bottles using the bulk CO_2 tank at Michael Shipley's house.[5] Mr. Bates left Mr. Shipley's house and brought his paintball equipment back to his house around dusk (approximately 6:20pm).[6,7] Mr. Bates used to keep his paintball equipment indoors in a china cabinet in the dining room area.[8] During the night of February 1st, 2015 the burst disk on one of Mr. Bates' CO_2 bottles burst.[9,10]

On the next day, on Monday February 2nd, 2015, Mr. Bates went to the Dunham Sports store and purchased paintball supplies at 4:24 pm.[11] Mr. Bates attempted to purchase a replacement PRD, but the Dunham Sports store did not have a replacement PRD.[12] At around 6pm, Mr. Bates was at home accompanied by his mother, Hilda Bates, and his son, Zen Bates. Mr. Bates was applying camouflage tape to the exterior of the CO_2 paintball bottle in the kitchen area. The

[1] Bates-000076.

[2] Deposition of Michael Shipley, Page 96.

[3] Deposition of Michael Shipley. Page 96; Deposition of Star Shipley, Page 91.

[4] Deposition of Star Shipley, Page 85 and 91.

[5] Deposition of Star Shipley, Pages 41-42 and 89-90; Deposition of Michael Shipley, Pages 100-101.

[6] Deposition of Star Shipley, Pages 41-42 and 90-91.

[7] Dusk time in Cherryville, NC on Sunday, February 1, 2015 according to sunrise-sunset.org.

[8] Deposition of Zen Bates, Page 33.

[9] Deposition of Zen Bates, Pages 91-92.

[10] The temperature on the night of February 1, 2015 ranged from approximately 45°F to 55°F based on data obtained from Weather Underground for the Lincolnton-Lincoln County Regional Airport in North Carolina.

[11] Exhibit 15.

[12] Deposition of Zen Bates, Page 99.

CO_2 bottle ruptured causing "massive internal trauma" to Mr. Bates.[13] Both Ms. Hilda Bates and Mr. Bates' son, Zen, witnessed the incident. Zen then called 911.

Mr. Bates had ordered two paintball marker kits from Dick's Sporting Goods on December 8, 2014.[14] This included the subject 9 oz. bottle that ruptured but no other bottles.[15] On December 16th, 2014, Mr. Bates purchased additional paintball equipment, from the Dick's Sporting Goods store in Gastonia, North Carolina.[16] This purchase included two 20 oz. and one 12 oz. CO_2 bottles. The paintball equipment purchased by Mr. Bates included several refillable CO_2 bottles of various sizes,[17,18] Mr. Bates played paintball with a group on Sundays in the property of one of the members of the group, Mr. Shipley, in Cherryville, NC.[19,20,21] Initially, the group refilled the CO_2 bottles at the Dick's Sporting Goods store.[22] After at least two refills at Dick's Sporting Goods, the group rented their own bulk CO_2 tank and located it at Mr. Shipley's house.[23]

CO_2 Bottles Owned by Mr. Bates

Mr. Bates owned five CO_2 bottles:

- The subject 9 oz. bottle that ruptured (subject bottle)
- Two black 20 oz. JT bottles (CO_2 bottles #1 and #4)
- A fire patterned 20 oz. Brass Eagle bottle (CO_2 bottle #2)
- A black 12 oz. JT bottle (CO_2 bottle #3)

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[13] Bates-000076.

[14] Deposition of Dennis Tippmann, Exhibit 44.

[15] Deposition of Dennis Tippmann, Page 114.

[16] Exhibit 83; Deposition of Shane Zollo, Page 28.

[17] Deposition of Dennis Tippmann, Page 27.

[18] Exhibit 83.

[19] Exhibit 2.

[20] Deposition of Michael Shipley, Page 67.

[21] Deposition of Shane Zollo, Page 27.

[22] Deposition of William Adam Deck, Exhibits 81 and 82.

[23] Deposition of Michael Shipley, Page 28.

Mr. Bates typically used the 20 oz. bottles when playing.[24] The subject 9 oz. bottle was obtained as part of a kit purchased for his son, Zen, in December 2014. The burst disk of CO_2 bottle #3 had burst the night prior to Mr. Bates' death.[25]

Manufacture of the Subject Bottle

According to manufacturer of the subject bottle, Gayston, the 9 oz bottle (and associated pin valve and PRD) that ruptured was manufactured in conformation to ASTM F1750, F2553, F2653, and F2030 and the design of the bottle is certified to DOT 3AL and TC 3ALM.[26]

The Gayston-manufactured subject bottle was labeled with a 3AL1800 designation indicating a design service pressure of 1800 psi. Gayston 3AL1800 bottles possess a PRD and, in some cases, a level indicator.[27] The subject 9 oz. bottle, however, did not contain a level indicator. The PRD was part of the pin valve assembly sourced by BXD from Joxco, a manufacturer in China, and sold to Gayston.[28] Gayston then installed the pin valves into their bottles prior to distribution to Tippmann or other clients.[29]

The design of the pin valve, including the PRD, was reverse engineered from competitors by BXD and Joxco.[30] Engineering drawings provided by BXD that are reportedly for the subject PRD are shown in Figure 1 and Figure 2. BXD then hired Aaron Stephens to assist with the auditing of the manufacturing facility for the PRD.[31] Mr. Stephens, however, did not possess any formal education in mechanical engineering or consumer product design.[32]

[24] Deposition of Zen Bates, Page 37.

[25] Deposition of Zen Bates, Pages 91-92.

[26] Deposition of Andrew Sheldrick, Pages 88-89 & Exhibit 31; Deposition of Dennis Tippmann, Exhibit 38.

[27] Deposition of David Schmitz, Page 25.

[28] Deposition of Gail Selby, Page 38.

[29] Deposition of Andrew Sheldrick, Page 23.

[30] Deposition of Gail Selby, Page 42 and 45.

[31] Deposition of Aaron Stephens, Pages 11, 15-16.

[32] Deposition of Aaron Stephens, Page 12.

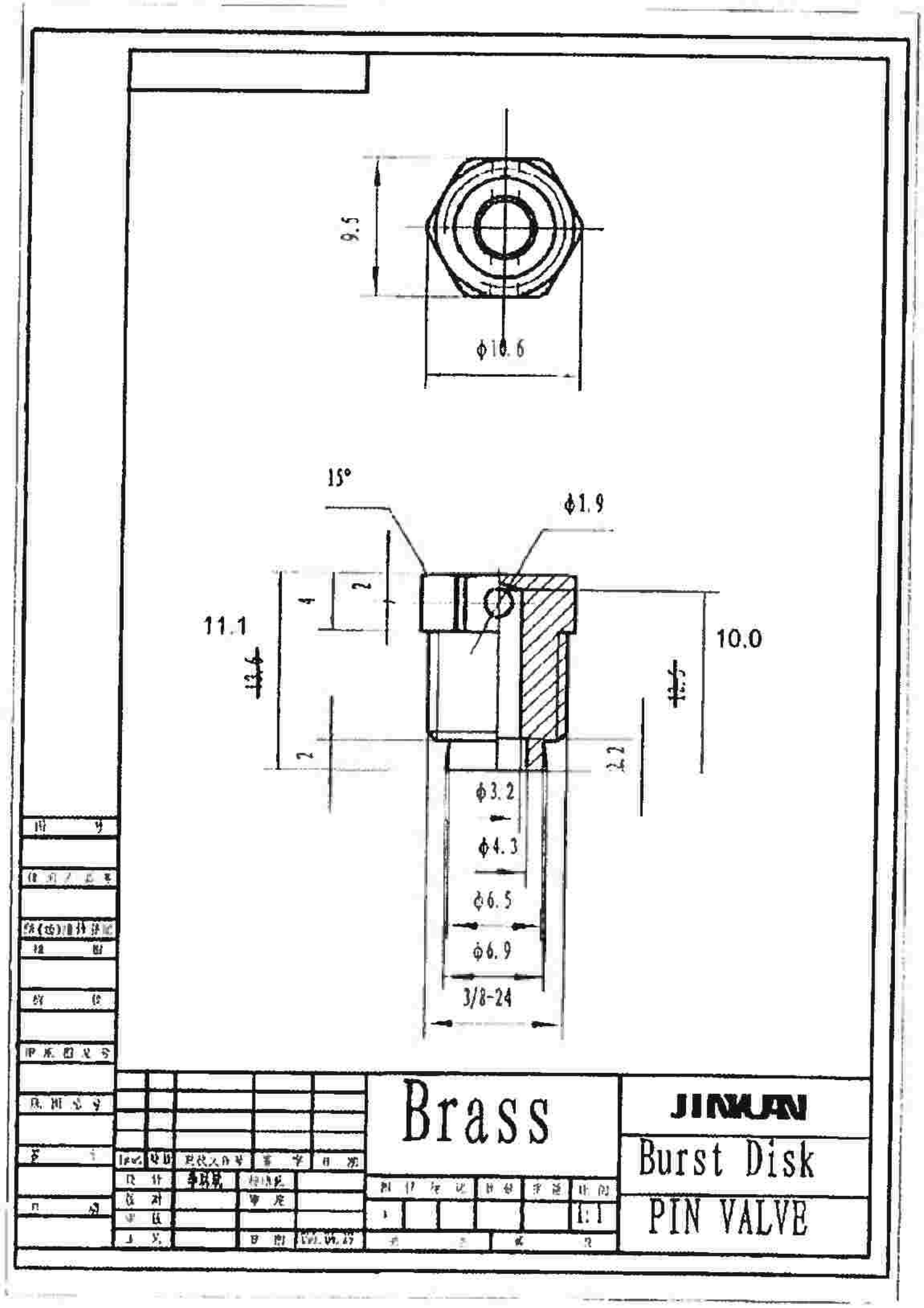

Figure 1. Engineering drawing provided by BXD reportedly used by Joxco for the assembly of the subject PRD brass threaded base (BXD0003).

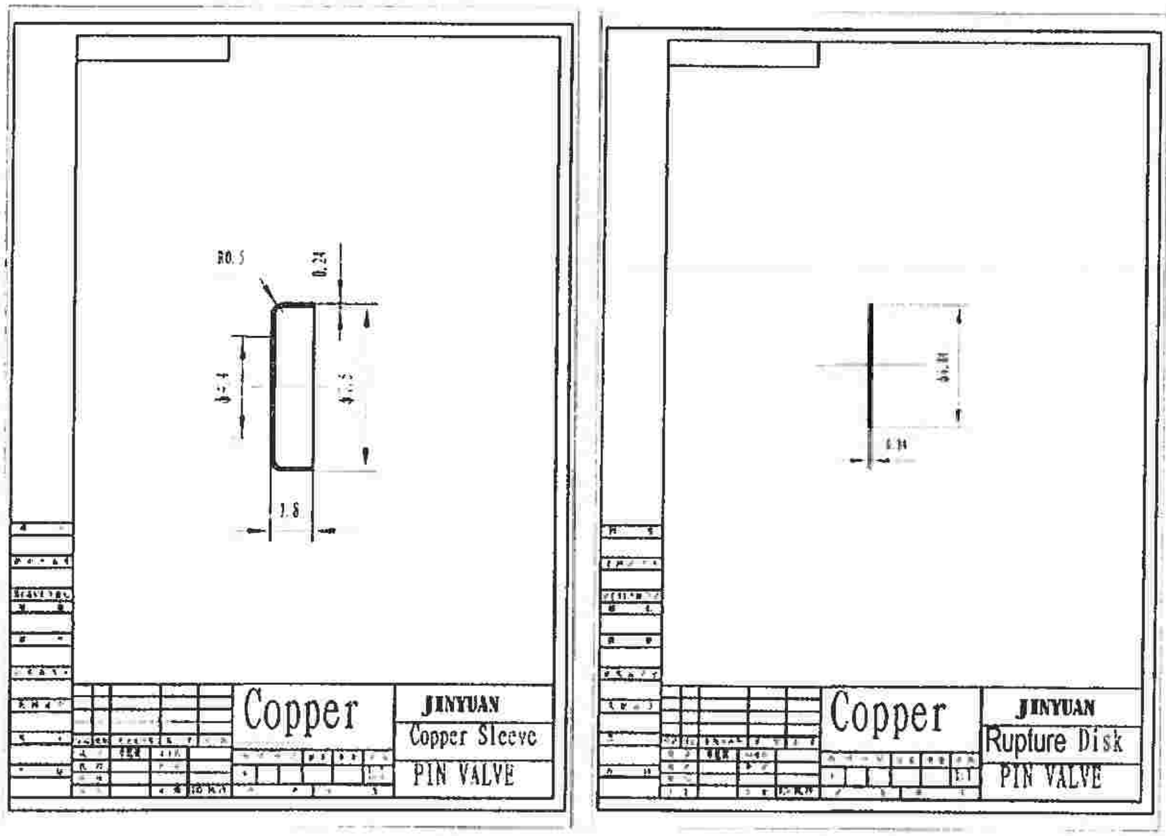

Figure 2. Engineering drawing provided by BXD reportedly used by Joxco for the assembly of the subject PRD cap and burst disk (BXD0004-BXD0005).

In the set of drawings (Figure 1 and Figure 2) produced by BXD that are purportedly representative of the PRD installed on the subject bottle, critical dimensions of the PRD are incorrect. For example, the burst disk, which on the incident and exemplar units has been measured to have a thickness of approximately 0.07 mm, is drawn and labeled as 0.14 mm. Similarly, the total height of the PRD based on the drawings would be 11.48 mm (0.452 inches). However, caliper measurements of the subject and exemplar PRDs yielded values between 12.47 and 12.60 mm (0.491 and 0.496 inches).

It is unclear if these inconsistencies represent a change in design that occurred between 2007 and when the subject PRD was manufactured or just incorrect documentation from the start of operations. Similarly, it is unclear if a set of design drawings that accurately reflect the subject PRD ever existed. Furthermore, we have found no material specifications for the copper used for the burst disk of the PRD in the reviewed documents. It was reported that thickness

measurements were made and samples were punched from incoming copper sheet and tested to confirm the burst pressure prior to punching the sheet for burst disks.[33]

In 2007, the manufacturing and assembly processes included punching holes out of copper sheets to form the burst disks.[34] The disks fell into a tray that was then brought across a courtyard to the assembly areas. The disk is then manually slid under a height gauge, which is intended to allow only one disk to pass at a time.[35] The worker sliding the disk under the height gauge was only allowed to work with one hand to prevent them from operating too quickly. A worker would then place the disk and a retaining cap onto the brass base and put the assembly through the crimping machine to secure the cap onto the base.[36] After crimping, according to Mr. Stephens, the cap was on tight such that it could not be removed by hand.[37] At the end of the assembly process, the height of components and the entire PRD were reportedly measured by caliper.[38]

Mr. Stephens made a single visit to the Joxco facility in April of 2007 and performed an audit of the facility.[39] During his audit, Mr. Stephens made recommendations including (1) checking the communication between the bore holes on the bottom of the PRD and the rest of the brass base[40] and (2) to not dump or pile the burst disks because that could lead them to stick together.[41]

After Mr. Stephens' visit, Joxco altered their process in an attempt to meet the ASTM and CGA required burst pressure range of 2,700 to 3,000 psi. In April 2013, for example, Joxco adjusted the thickness of the copper being used.[42] Also in 2013, an email from a Joxco employee to Gail Selby describing the precautions taken by Joxco to prevent multiple burst disks does describe

[33] Deposition of Aaron Stephens, Pages 23-24; Exhibit 144.
[34] Deposition of Aaron Stephens, Pages 23-24.
[35] Deposition of Aaron Stephens, Pages 25-26.
[36] Deposition of Aaron Stephens, Pages 21-22.
[37] Deposition of Aaron Stephens, Page 28.
[38] Deposition of Aaron Stephens, Page 68.
[39] Deposition of Aaron Stephens, Page 19.
[40] Deposition of Aaron Stephens, Page 20.
[41] Deposition of Aaron Stephens, Page 23.
[42] Deposition of Gail Selby, Exhibit 137.

the caliper measurements but does not mention the height gauge.[43] Therefore, it is unknown if the height gauge was still being used in 2013 or at the time of the manufacture of the subject PRD.

Joxco had a history of quality control issues and trouble meeting deadlines. Specifically, on November 30, 2012, Justin Matchett of Premiere Seals said in an email to Joxco that, "quality issues have been a nightmare."[44] Mr. Matchett also references the rejection of pin valves produced by Joxco, mixing up o-rings, and concerns with Joxco suppliers. In 2009, testing performed by Gayston of standalone PRDs (not installed in pin valves) provided by Joxco indicated failure pressure well above design.[45] Inconsistent burst pressures led to 200,000 PRDs being returned in May 2009.[46] When Joxco requested in June 2009 to increase prices, BXD told them that a price increase "is not possible right now."[47] BXD described their own product as being "marginal" and needing to compete on price rather than quality.[48] BXD attempted to handle Joxco's quality problems by shifting the "marginal product" to different customers.[49] In 2013, Mr. Selby of BXD stated that he was not sure BXD could guarantee that all burst disks will burst at the ASTM F2030 required 2,700 to 3,000 psi "at this price point".[50]

Testing and Documentation of the PRDs

BXD, Gayston, Tippmann, and Dick's Sporting Goods all handled PRDs produced by Joxco prior to distribution to customers. Between the four entities and Joxco, no regular documentation of PRD testing is available. Some testing of the PRDs was reportedly performed by Joxco, but in 2013, a Joxco employee describes the testing as occurring once per week rather than per number of units produced.[51] In the event of an out-of-specification test, the employee

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[43] Deposition of Aaron Stephens, Exhibit 144.
[44] BXD005463
[45] BXD009583-BXD009584
[46] BXD009865
[47] BXD007185
[48] BXD007186
[49] BXD007185
[50] Deposition of Gail Selby, Exhibit 136.
[51] Deposition of Aaron Stephens, Exhibit 144 (BXD005475).

states that immediate adjustment will be made. This procedure is inconsistent with the CGA S-1.1 standard that requires testing of two PRDs in each lot of 3,000 units and to reject the entire lot if a disk is found to be outside of the prescribed 2,700 to 3,000 psi range.[52] Conversely, Gail Selby of BXD stated that there was a non-written understanding that Joxco would scrap the entire lot in the event of a failed test, but no failure had ever been reported to BXD.[53] According to BXD, all of the PRDs were leak tested to ensure they had been properly torqued into the pin valve.[54]

BXD did reportedly perform burst testing on PRDs in accordance with CGA S-1.1.[55] However, documentation for the lot from which the subject PRD originated could not be confirmed. Testing reports that have been produced by BXD do not indicate whether sufficient PRDs were tested but do indicate that values outside the range of the ASTM F2030 and CGA S-1.1 standard were obtained.[56]

Gayton, when receiving valves from BXD did not request documentation of testing on the valve assemblies, but rather relied on the testing of a client, Kee Action Sports.[57] According to Andrew Sheldrick of Gayston, Gayston did not perform any testing of their own on the PRDs.[58] David Schmitz, also of Gayston, however, did state that testing was performed when specific concerns were raised.[59]

Tippmann did not receive certifications or other documentation from Gayston to confirm that the PRDs were compliant with the ASTM F2030 or CGA S-1.1 standards.[60] Tippmann did state

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[52] See late section entitled, *CGA S-1.1 – Pressure Relief Device Standards Part 1 – Cylinders for Compressed Gases*.

[53] Deposition of Gail Selby, Page 62.

[54] Deposition of Gail Selby, Pages 51-52.

[55] Deposition of Aaron Stephens, Pages 44-45.

[56] Deposition of Aaron Stephens, Exhibit 141.

[57] Deposition of Andrew Sheldrick, Pages 25-26.

[58] Deposition of Andrew Sheldrick, Page 30.

[59] Deposition of David Schmitz, Pages 26-28.

[60] Deposition of Dennis Tippmann, Pages 63-64.

that testing, including burst disk testing, was performed on one out of every 1,000 bottles.[61] No documentation of that testing, however, has been found in the production materials. Dick's Sporting Goods does not perform any burst testing of products purchased from Tippmann.[62]

Carbon Dioxide Thermodynamics

Carbon dioxide is used at a propellant in paintball markers. The Tippmann 9 oz. bottle that ruptured and killed Mr. Bates is designed to contain CO_2 in a pressure-liquefied or two-phase state, containing both gas and liquid. The fraction of volume occupied by vapor is strongly dependent on temperature. As temperature increases, the vapor volume fraction decreases and the liquid level rises correspondingly. Most of the time, as long as there is some vapor in the bottle, the pressure in the bottle is solely controlled by the temperature and is equal to the saturated vapor pressure.

However when the bottle becomes full of liquid with no vapor remaining, the bottle pressure may rise significantly. In this condition, the pressure will rise rapidly with relatively small increases in temperature. The Tippmann 9 oz. bottle that ruptured and killed Mr. Bates failed because it reached and exceeded the saturated liquid condition. Figure 3 and Figure 4 show the pressure as a function of temperature for several fill weights in a 9 oz. Tippmann bottle.[63] Calculations were based on CO_2 properties from the National Institute of Standards and Technology's (NIST) Reference Fluid Thermodynamic and Transport Properties Database (REFPROP) software.

[61] Deposition of Dennis Tippmann, Pages 87-88.

[62] Deposition of Douglas Stipanovich, Page 35.

[63] The 9 oz nominal capacity is the rated weight. Depending on the temperature and pressure, more than 9 oz of CO_2 can fit within the bottle.

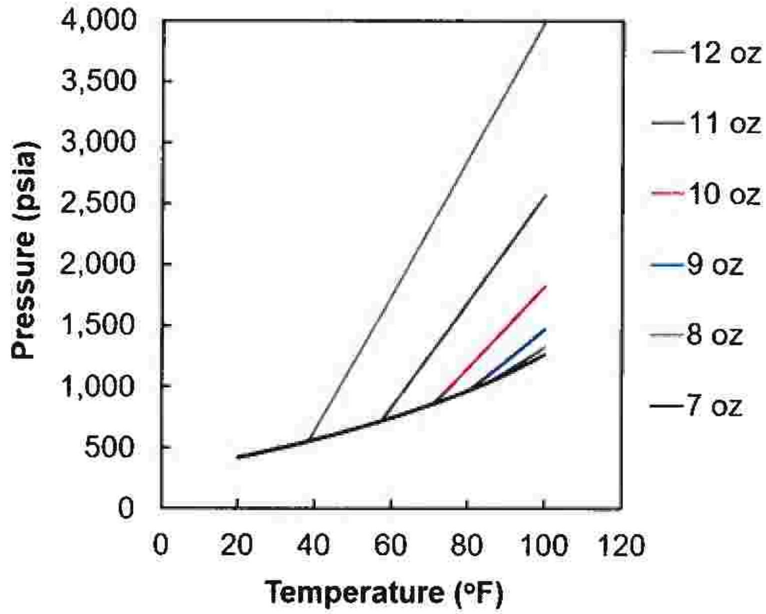


Figure 3. Pressure as a function of temperature for equilibrium CO_2 stored in a bottle of the same volume as the subject Tippmann 9 oz. bottle. All oz. measurements refer to mass (not volume).

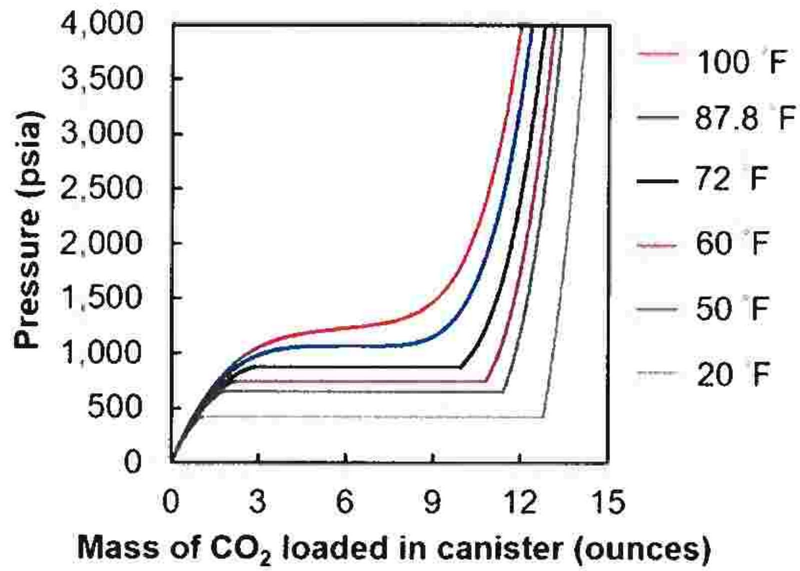


Figure 4. Pressure as a function of fill weight for equilibrium CO_2 stored in a bottle of the same volume as equivalent to the subject Tippmann 9 oz. bottle.

As can be seen in Figure 3, the pressure increases relatively slowly with temperature and independently of the fill weight until a transition occurs, at which point, the pressure rapidly rises. The transition occurs at the saturated liquid condition and it represents a change from a gas/liquid two-phase mixture to a fully hydraulic state (all liquid). Figure 3 shows that a 9 oz.

bottle that is filled with 12 oz. of CO_2 begins to experience a rapid increase in pressure at around 38.5°F and reaches a pressure of 3,000 psi at a temperature near 82.3°F. Similarly, an 11.5 oz. fill of CO_2 begins to experience a rapid increase in pressure at around 48.5°F and reaches a pressure of 3,000 psi at a temperature near 96.5°F.

Bottles with 20 oz. capacity are expected to provide 800-1000 shots per fill whereas 9 oz. bottles are expected to provide 300-500 shots per fill.[64] Overfilling of a CO_2 bottle would not substantially change the pressure at which paintballs are fired because the additional volume of the hose and firing mechanisms would return a fully hydraulic system back to a two-phase regime, at which point the temperature would define the pressure of the system, not the fill level. While overfilling a 9 oz. bottle could marginally increase the number of shots per fill, a properly filled 20 oz. bottle would still provide a substantially greater number of shots than a 9 oz. bottle. Since Mr. Bates owned two 20 oz. bottles and a 12 oz. bottle, there is no logical benefit to overfill the 9 oz. bottle.

Filling of CO_2 Bottles

The ASTM provides the following recommended steps for filling CO_2 bottles:[65]

> ***7. CO_2 Fill Procedures***
>
> *7.1 The safety relief device, cylinder wall, and valve body assembly of all cylinders to be transfilled must be inspected as described in Section 6. If a condition not described in Section 6 is found and is of concern of the person transfilling the cylinder, the cylinder must not be filled.*
>
> *7.2 CO_2 should only be filled by weight, never pressure.*
>
> *7.3 If so equipped, close the valve on the paintball cylinder.*
>
> *7.4 Attach the CO_2 fill station to the supply cylinder. Ensure that the CGA 320 fittings are used and installed correctly. Ensure that only one (1) correct sealing washer is used.*
>
> *7.5 Deactivate the universal fill adaptor (UFA). Attach the paintball cylinder to the CO_2 fill station using the UFA.*

[64] Based on specifications found at http://www.tippmann.com/.

[65] ASTM F2856-12

7.5.1 Invert the paintball cylinder, open paintball cylinder valve and/or activate the UFA and the blow-down valve to fully discharge the remaining CO_2.

7.5.2 Weigh the empty cylinder. Determine the allowable net weight of CO_2 and add this value to the empty cylinder weight. This provides the gross weight of a full cylinder. The bottle should be cool to the touch in order to receive the CO_2.

7.5.3 If no venting occurs, add 1 to 2 oz and repeat the inversion and depressurization.

7.5.4 Conduct a valve twist test on the depressurized cylinder as stated in 6.1 and 6.2.

7.6 Fill the cylinder to the proper gross weight.

7.6.1 To fill the paintball cylinder, open the valve to the paintball cylinder, activate the UFA, close the blow-down valve, and open the supply valve to begin transfer of the CO_2.

7.7 To complete the transfilling process, close the supply valve, de-activate UFA and the valve of the paintball cylinder, and open the blow-down valve to vent the supply line. Check the final weight of the paintball cylinder.

7.8 If the final weight is below the allowable gross weight of the cylinder, close the transfer valve, open the blow-down valve to relieve some pressure from the paintball cylinder and repeat steps above for filling.

7.9 If the final weight exceeds the allowable gross weight of the cylinder, vent the excess CO_2. Do not overfill the cylinder.

7.10 Turn off the supply tank, safely vent down the fill station and if possible, remove or secure any hoses. Do not leave CO_2 in the fill station or hoses when not in use.

Several inconsistencies are observed between the ASTM methodology and the methods used by Dick's Sporting Goods.[66] Three different resources are available to Dick's Sporting Goods employees: (1) the training manual, (2) an operations poster in the fill area, and (3) a reference sheet.

In Step 7.8 of the ASTM methodology, the operator is instructed to purge additional CO_2 in the event that the initial fill is under the nominal capacity of the system. This step is absent from the three references available for Dick's Sporting Goods employees. Exponent performed testing using 9 oz Tippmann bottles and the filling procedure outlined by the Dick's Sporting Goods'

[66] Deposition of William Deck – Exhibits 70, 77, 80.

documentation. Using the procedure, it was not possible to fill the bottle to its nominal capacity. Specific results are shown in Table 1 below.

Table 1. Fill testing results using Dick's Sporting Goods methodology on a 9 oz Tippmann bottle.

Initial CO_2 Quantity (oz)	CO_2 After Purge (oz)	CO_2 After Fill (oz)
0	0	5.5
5.4	0	7.3

The three sources of information for Dick's Sporting Goods employees regarding CO_2 bottle filling are inconsistent on the action to take if ice is observed on the outside of the bottle. The training manual states that the bottle should be put aside for 15 minutes if ice is observed, while neither the reference sheet nor poster indicate that is necessary. The ASTM standard also does not include such a waiting step.

Testing performed by Exponent where the purge was performed with the bottle right-side-up indicated that one or more ounces of frozen CO_2 (dry ice) can be formed within the bottle.[67] Results from the testing are shown in Table 2. Dry ice formed during an initial purging step could result in an inaccurate tare weight and subsequent over-filling.

Table 2. Purge testing on a 9 oz Tippmann bottle.

Initial CO_2 Quantity (oz)	CO_2 After Purge (oz)	CO_2 After Fill (oz)
7.3	1.1	11.0
11.0	2.2	Not tested

No tare weight was marked on the subject Tippmann 9 oz CO_2 bottle as is required for some other pressure-liquefied gases including propane.[68] A marked tare weight would allow the user to compare their tare weight against the original manufacture weight to confirm an accurate tare.

[67] Purging with the CO_2 bottle right-side-up is consistent with online videos on how to fill CO_2 bottles.
[68] NFPA 58 (2014) – Section 5.2.8.2.

Despite Dick's Sporting Goods employee training, numerous accounts of PRD's bursting after being filled have been reported. These may be the result of either overfilling, high temperatures, or a combination of the two. A series of complaints by Dick's Sporting Goods customers have documented these burst disk failures. These complaints include:[69]

- On April 27, 2013, a report was issued about an August 2012 event where the burst disk on a CO_2 bottle purchased as part of a paintball kit ruptured causing frost bite injuries to a child's hands.
- On May 14, 2013, a customer reported a CO_2 discharge from a CO_2 bottle. According to the report, one explanation for the incident was that the bottle may have been "slightly overfilled". An investigation indicated that the burst seal had failed.
- On February 25, 2014, a CO_2 bottle discharged in the back seat of a customer's car. In this instance, the Dick's Sporting Goods employee had filled the bottle a second time after a small amount vented out of the valve following the first fill. The employee who filled the bottle also noted that the bottle was colder than normal.
- On August 5, 2014, a CO_2 bottle was filled at Dick's Sporting Goods and then exploded in the car in the customer's son's face.
- On December 29, 2014, a customer reported that a burst disk for a purchased CO_2 bottle ruptured after having been filled in the store.
- On January 11, 2015, a CO_2 bottle was filled at Dick's Sporting Goods and then exploded in the customer's son's face.
- On February 6, 2015, a customer reported that a burst disk in a CO_2 bottle filled by Dick's Sporting Goods ruptured in his bedroom and damaged his dresser.
- On December 5, 2015, a CO_2 bottle that had just been filled by the Archery department of a Dick's Sporting Goods ruptured its burst disk at the store checkout counter.
- On December 18, 2015, a customer reported that a burst disk for a CO_2 bottle ruptured in their car after having been filled in the store.
- On February 21, 2017, a customer reported that a burst disk for a CO_2 bottle ruptured in their car after having been filled in the store.

[69] Deposition of Douglas Stipanovich, Exhibits 91 to 103.

Scientific Methodology

In the following sections, the scientific method is applied to evaluate a variety of hypotheses based on allegations and a review of the documentation, process data, and relevant literature. A thorough description of the scientific method can be found in NFPA 921, *Guide for Fire and Explosion Investigations* published by the National Fire Protection Association.[70] Additional information regarding the evaluation of technical and scientific material is provided in ASTM E678-07(2013), *Standard Practice for Evaluation of Scientific or Technical Data*. Once the need for an investigation is identified, the scientific method includes the following major steps:

1. Definition of the problem
    a. Determine the relevant issues, investigative methods, and types of data to collect.
2. Collection of data
    a. Gather documentation, process data, depositions, etc.
3. Analysis of data
    a. Review the data. Perform calculations, comparisons, timelines of events, etc.
4. Hypothesis development (inductive reasoning)
    a. Based on the analyzed data, produce a hypothesis that could explain the observed phenomena.
5. Hypothesis testing (deductive reasoning)
    a. Test the hypothesis against all the available evidence in an attempt to disprove the hypothesis. Hypotheses can be tested through accepted scientific principles or through referring to scientific research. A hypothesis that cannot be tested is not a valid hypothesis.
6. Select final hypothesis
    a. After all the developed hypotheses have been tested against the available evidence, the hypothesis (or hypotheses) that are consistent with the available evidence.

[70] NFPA 921: *Guide for Fire and Explosion Investigations*. National Fire Protection Association (2017) Chapter 4.

Pressure Liquefied Gas Regulations and Standards

DOT Standards[71]

The specifications of DOT regulated cylinders such as the subject cylinder involved in this case are specified in several sections of the Code of Federal Regulation (*i.e.* CFR) including but not limited to (1) 49 CFR 173, (2) 49 CFR 178, and (3) 49 CFR 180.

Section 49 CFR 173 covers several aspects of the general qualifications for the use of DOT specifications cylinders. In the context of Pressure Relief Device Systems, 49 CFR 173.301(f) states that:

> *A cylinder filled with a gas and offered for transportation must be equipped with one or more pressure relief devices sized and selected as to type, location, and quantity, and tested in accordance with CGA S-1.1 [...] and CGA S-7.*

The pressure relief device (PRD) in the subject cylinder consists of a burst disk assembly installed on top of the cylinder.

The filling requirements are also addressed by 49 CFR 173. In particular, 173.304a – *Additional requirements for shipment of liquefied compressed gases in specification cylinders*- discusses the maximum filling amounts of DOT specification cylinders. The maximum permitted filling density for a DOT 3AL cylinder containing CO_2 is 68% where filling density is defined as

> *The percent ratio of the weight of gas in a packaging (i.e. cylinder) to the weight of water that the container will hold at 16°C (60°F)*[72].

The internal volume of the subject DOT 3AL cylinder is 22.9 in^3,[73] corresponding to a water capacity of 0.826 lbs. The corresponding maximum filling limit for CO_2 is 0.562 lbs. or 9 oz. At

[71] Note that CO_2 bottles are referred to as cylinders in most standards and regulations.

[72] 1 lb. of water corresponds to 27.737 in^3 at 60°F.

[73] GS0064 – Certificate of Compliance and Test Report for DOT-3AL1800 cylinder.

32°F, 9 oz. of CO_2 represents a 73% fill by liquid volume. At 72°F, 9 oz. of CO_2 represents a 91% fill by liquid volume. At approximately 80°F, 9 oz. of CO_2 represents a 100% fill by liquid volume.

The Code of Federal Regulation prescribes a methodology to verify the content of the cylinder. Section 49 CFR 173.304a(c) states that

> *The amount of liquefied gas filled into a cylinder must be by weight. [...] The weight of liquefied gas filled into the cylinder also must be checked, after disconnecting the cylinder from the filling line, by the use of an accurate scale.*

The same section of the Code of Federal Regulation covers the filling requirements for propane cylinders. In particular, the filling density limits is 42% of the water-weight capacity for DOT specifications cylinder containing commercial propane.[74] As an example, common 20 lbs. propane cylinders used in gas grills have a water capacity of approximately 48 lb. Using the prescribed filling limit of 42%, the corresponding maximum amount of propane that can be dispensed in 20-lbs cylinder is in fact 0.42×48lb or 20lb.

The Code of Federal Regulation (Section 49 CFR 173.301(a) (2)) states that

> *[...] the person filling the cylinder must visually inspect the outside of the cylinder. A cylinder that has a crack or a leak, is bulged has a defective valve or a leaking or defective pressure relief device, or bear evidence of physical abuse, fire or heat damage, or detrimental rusting or corrosion may not be filled and offered from transportation.*

The subject cylinder contains no warnings that inform the user of the safety issues associated with cylinders that show evidence of physical abuse such as dents or gouges on the outside of the cylinder.

[74] The filling density limit for commercial propane has been obtained assuming a specific gravity at 60°F for liquid propane equal to 0.504 (LP-Gas Code Handbook, NFPA 58, 2011 Edition, Annex B).

The design specifications of DOT 3AL cylinders are prescribed in section 49 CFR 178.46 – *Specifications 3AL seamless aluminum cylinders.* According to the Code of Federal Regulation, a DOT 3AL cylinder is a seamless aluminum cylinder with a maximum water capacity of 1,000 pounds and a minimum service pressure of 150 psig. Both requirements are fulfilled by the subject cylinder.

The manufacturing and testing requirements of DOT 3AL cylinder are presented in section 49 CFR 178.46. According to the Code of Federal Regulation, each cylinder design should be qualified for production by testing prototype samples as follows:

> *Three samples must be subjected to 100,000 pressure reversal cycles between zero and the service pressure or 10,000 pressure reversal cycles between zero and the test pressure [...]*

It should be noted that the Code of Federal Regulation defines the *test pressure* as five-thirds of the *service pressure* of the cylinder.[75] The service pressure is defined as the cylinder operating pressure indicated by the markings placed on the cylinder by the manufacturer. The subject cylinder has a *service pressure* of 1,800 psig that results is a *test pressure* of 3,000 psig.

According to the federal code, each cylinder must be subjected to a hydrostatic test where the cylinder is subjected to an internal *test pressure* using a water jacket equipment or other suitable apparatus. During the hydrostatic test, the cylinder is subjected to the *test pressure* for a period of time of at least 30 seconds and long enough to assure the complete expansion of the cylinder. The tested cylinder shall not experience a permanent volumetric expansion larger than 10% of the total volumetric expansion attained at the *test pressure.* For three samples of a given design, it is specified by the code that

> *[t]he sample must be pressurized to destruction and failure may not occur at less than 2.5 times the marketed cylinder service pressure.*

[75] 49 CFR 178.46(g)(3)(iii).

For the subject cylinder with a service pressure of 1,800 psig, the minimum failure pressure is 4,500 psig.

ASTM F2030 - Paintball Cylinder Burst Disk Assemblies

The subject cylinder was equipped with a PRD consisting of a burst disk assembly installed on the top of the cylinder. The characteristics of the PRD are specified by the ASTM Standard F2030-11 – *Standard Specification for Paintball Cylinder Burst Disk Assemblies.* This standard shares some of the technical details already presented in the previous section covering the DOT standard. Specifically, ASTM F2030 defines the test pressure as 5/3 of the cylinder's service pressure.

According to ASTM F2030, the PRD (1) *shall be marked with its maximum rated bust pressure* and (2) *must rupture between 90 and 100% of the test pressure.* The subject cylinder had a service pressure of 1,800 psig, corresponding to a test pressure of 3,000 psig. The corresponding specifications for the burst disk require it to rupture at between a minimum of 2,700 psig (i.e. 90% of the test pressure) and a maximum of 3,000 psig (i.e. 100% of the test pressure). Furthermore, the standard specifies that

> *The burst disk assembly will be of single use design (non-user resettable or rebuildable). Therefore, if activated, this will require the replacement of the entire burst disk.*

CGA S-1.1 – Pressure Relief Device Standards Part 1 – Cylinders for Compressed Gases

As stated previously, 49 CFR 173.301(f) requires that cylinders offered for transportation contain at least one pressure relief device in accordance with CGA S-1.1. A burst disk assembly on the subject CO_2 bottle is a type CG-1 pressure relief device. CG-1 PRDs are subject to several requirements in the standard including:[76]

[76] Deposition of Dennis Tippmann, Exhibit 40. Sections 4.2, 6.3.1, and 6.3.13.

When a rupture disk device is used as a pressure relief device on a compressed gas cylinder, the rated bursting pressure of the disk when tested at the specified design temperature within the range of 60 °F to 160 °F (15.6 °C to 71.1 °C) in accordance with 6.3 shall not exceed the minimum required test pressure of the cylinder with which the disk is used

The production of rupture disks shall be segregated into lots of not more than 3000 disks with appropriate control exercised to ensure uniformity of production. Representative samples shall be selected at random for testing to verify the rated bursting pressure. The number of samples selected shall be appropriate for the manufacturing procedures followed, but at least two samples shall be tested from each lot. Samples shall be mounted in a proper holder with a pressure opening having dimensions identical with that in the device in which it is to be used and submitted to a burst test at a temperature not lower than 60 °F (15.6 °C) nor higher than 160 °F (71.1 °C). The test pressure may be raised rapidly to 85% of the rated burst pressure, held there for at least 30 seconds, and thereafter shall be raised at a rate not in excess of 100 psi (689 kPa) per minute, until the disk bursts. The actual burst pressure of the disk shall not be in excess of its rated burst pressure and not less than 90% of its rated burst pressure.

If the actual burst pressure is not within the limits prescribed above, the entire lot of rupture disks shall be rejected. If the manufacturer so desires, four more disks selected at random from the same lot may be subjected to the same test. If all four additional disks meet the requirement, the lot may be used; otherwise, the entire lot shall be rejected.

Regulations for Other Pressure Liquefied Gases

The safety issues associated with overfilling cylinders with pressure liquefied gases have been known for decades. Furthermore, this issue is common in several contexts including, but not limited to, the transportation and shipping of propane filled cylinders.

In response to the problem of overfilled propane cylinders, the propane industry has undertaken a number of steps to mitigate or eliminate this issue. In particular, starting from late 1990s, NFPA 58 – Liquefied Petroleum Gas Code - required all small portable cylinders to be equipped with an Overfilling Prevention Device (OPD). An OPD is a safety device and a part of the cylinder valve assembly that actuates and shuts the flow of gas during the filling process when the liquid level reaches the maximum filling limit.[77]

Fixed maximum liquid level gauges are also found on propane cylinders. They typically consist of a dip tube and a bleeder valve located on the cylinder valve assembly. The fixed maximum liquid level gauges are designed to connect the interior of cylinder to the external environment via a small orifice. A screw located on the valve is used to open or close the pathway through the orifice. During the filling process, the bleeder valve is open, as soon as the liquid level reaches the bottom of the dip tube, small amounts of liquid propane are released to the external environment indicating to the person delivering the propane that the maximum filling limit has been reached. Fixed maximum liquid level gauges have been successfully used for many years to minimize the risk of overfilling a propane cylinder.

To assist users filling by weight rather than volume, the tare weight of the propane tank is permanently marked onto the cylinders.[78]

[77] NFPA 58 (2014) – Section 5.7.3.

[78] NFPA 58 (2014) – Section 5.2.8.2.

Evidence Examinations

The following evidence was retained from Mr. Bates' possessions and the possessions of his friend Mr. Shipley:

- Subject 9 oz Tippmann bottle
- Mr. Neman's watch
- Project Salvo Paintball marker
- Alpha Elite Paintball marker
- CO_2 bottle 1
- CO_2 bottle 2
- CO_2 bottle 3
- CO_2 bottle 4
- Digital scale
- CO_2 filling valve and hose
- Camouflage tape
- Rubber O-rings
- Narrow pipes
- Paintball helmet with built-in goggles
- Black Tippmann holster belt
- Camouflage Valken holster
- Boxes of paintballs (Munition, Blaze, Infinity)
- Project Salvo Marker Box
- Alpha Elite Marker Box
- Wand cleaners
- Marker tip
- Fill hose (black)
- Cyclone feed system box
- E-trigger packaging
- Helmet visor
- Allen camouflage tape
- Bazzor barrel package
- Avenger trigger assembly
- Black Eagle trigger assembly
- Miscellaneous hardware

Initial Inspection

Prior to joint evidence examinations (discussed later), non-destructive visual inspection and CT scanning of the subject CO_2 bottle were performed. Inspection of the subject bottle indicated it was marked as a DOT 3AL1800 bottle with a nominally 9 oz CO_2 capacity. The bottle was manufactured in November 2014, had been hydrostatically tested, had the serial number of

P001927, and manufacturer code M4625. Based on deposition testimony from Andrew Sheldrick, the subject bottle was manufactured by Gayston.[79]

An exemplar bottle made in December 2014 with the same manufacturer code and serial number P028731 was also examined. The observed markings on the subject CO_2 bottle, the exemplar CO_2 bottle, and the other CO_2 bottles owned by Mr. Bates are shown in Table 3.

Table 3. Summary of bottles examined by Exponent.

	Subject	Exemplar	Bottle #1	Bottle #2	Bottle #3	Bottle #4
Transportation Agency Designation	DOT / TC	DOT / TC	DOT / TC	DOT / TC	DOT / TC	DOT / TC
Specification Standard and Material	3AL / 3ALM 124	3AL / 3ALM 124	3AL / 3ALM 124	3AL / 3ALM 124	3AL / 3ALM 124	3AL / 3ALM 124
Service Pressure	1800	1800	1800	1800	1800	1800
Serial Number	P001927	P028731	N980822	G970021	N901554	N956424
Manufacturer Code	M4625	M4625	M4625	M4625	M4625	M4625
Month/Year of Hydrostatic Test	11 / 14	12 / 14	10 / 14	12 / 05	08 / 14	10 / 14
Rated Capacity	09 oz CO2	09 oz CO2	20 oz CO2	20 oz CO2	12 oz CO2	20 oz CO2

CT scanning of the entire subject bottle and exemplar bottles were performed. A three-dimensional rendering from the scan of the subject CO_2 bottle is shown in Figure 5. The measured wall thickness of the incident and exemplar bottles indicate a wall thickness of approximately 2.35 mm (0.093 inches) to 2.5 mm (0.098 inches) for both bottles.

[79] Deposition of Andrew Sheldrick, Page 20.

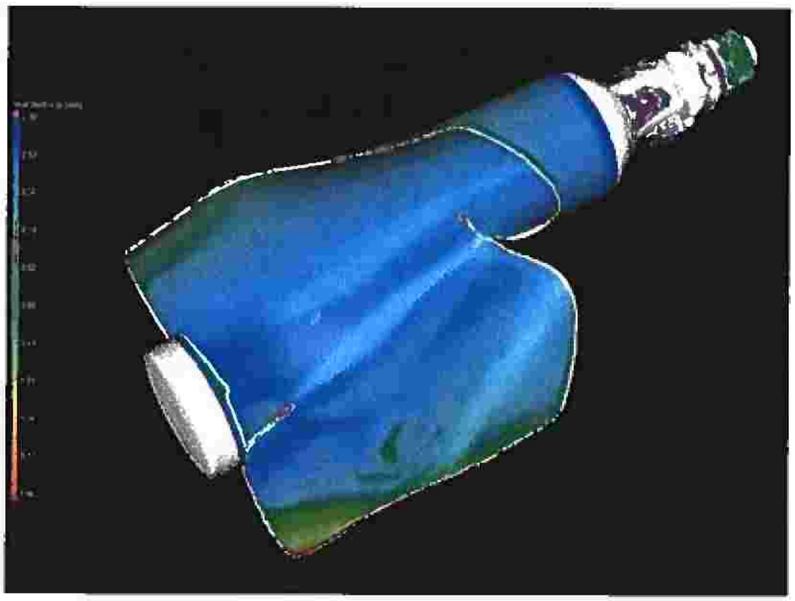


Figure 5. Three-dimensional rendering of the subject CO_2 bottle from CT scan data.

In addition to the examination of the CO_2 bottles, testing of the scale used by Mr. Bates was performed using calibrated weights. The testing indicated the gauge was functioning properly. The results of the testing are shown in Table 4.

Table 4. Results of scale testing.

Calibrated Weight	Scale Measurement	Error
9 oz. (255 grams)	8.9 oz.	1.1%
9 oz. (255 grams) repeat	8.9 oz.	1.1%
20 oz. (565 grams)	20.1 oz.	0.5%
13.8 oz. (392 grams)	13.9 oz.	0.7%
9 oz. (255 grams) with 13.8 oz initial tare	8.9 oz.	1.1%

A series of four joint evidence examinations were performed at Exponent's Natick, Massachusetts facility. A description of the work from each examination is provided below.

March 17, 2017

In this examination, the paintball markers and subject bottle were examined through visual inspection. Furthermore, detailed optical microscopy and computed topography (CT) of the incident bottle and pin valve were performed.

Visual Inspection

A visual inspection of the incident bottle was performed. A photograph of the ruptured bottle is shown in Figure 6. Photographs of the pin valve are shown in Figure 7. It was observed that the pin valve was dated 7/14 indicating a manufacture date in July 2014. Damage to the threads of the pin valve was also observed.

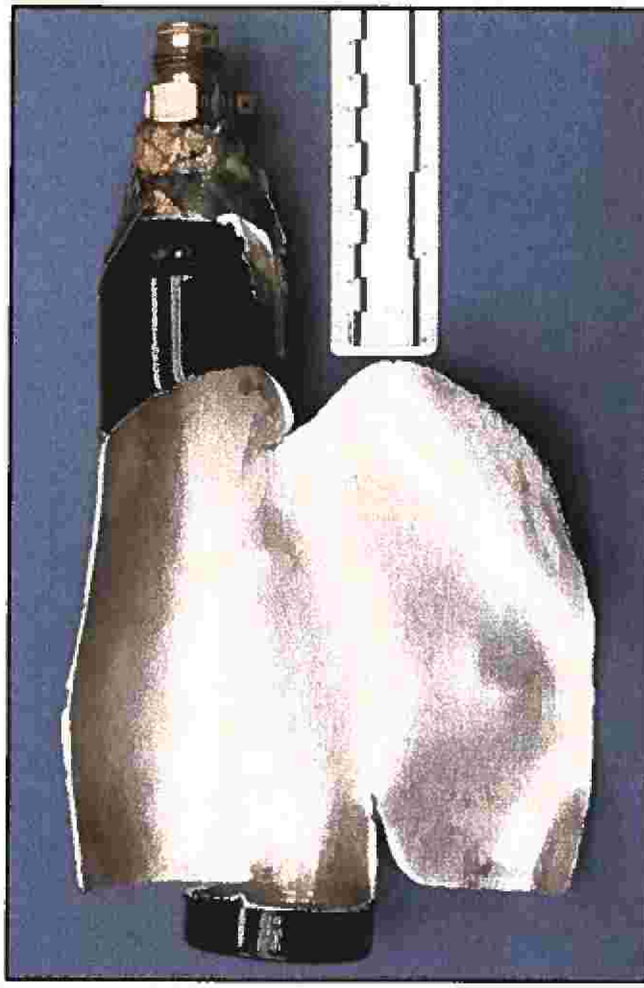


Figure 6. Photograph of the subject Tippmann CO_2 bottle that ruptured and killed Mr. Bates.

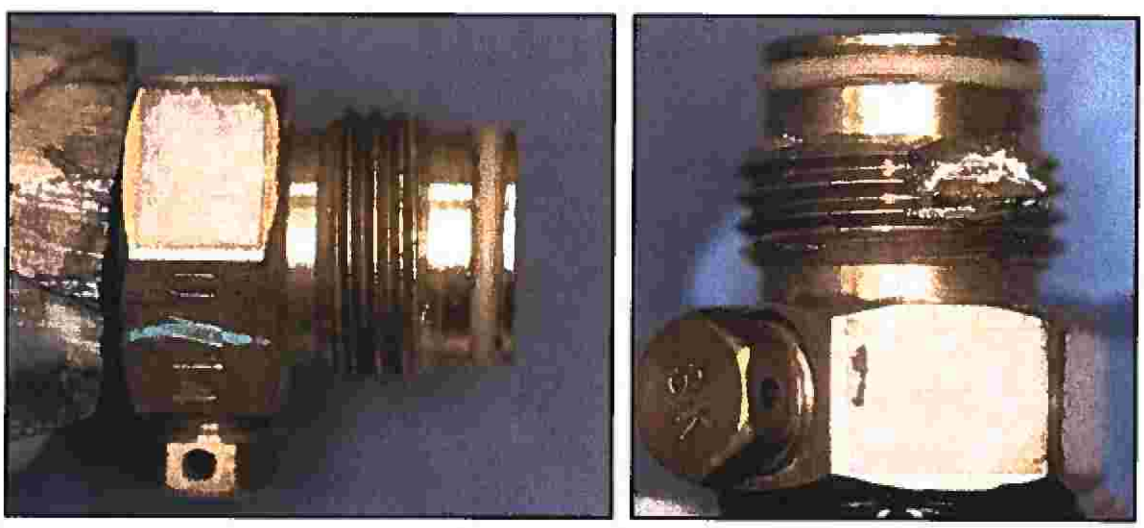


Figure 7. Photographs of the pin valve on the subject CO_2 bottle.

Optical Microscopy

Optical microscopy images were taken of the left and right sides of the fracture shown of the subject bottle shown in Figure 6. A representative fracture image is shown in Figure 8.

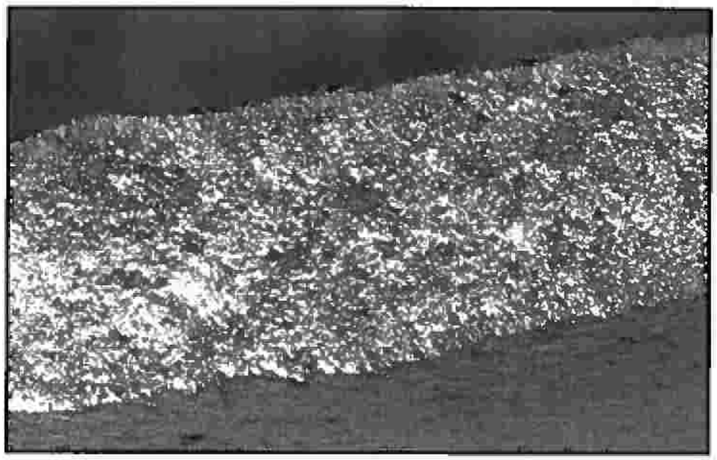


Figure 8. Optical micrograph of the left side of the fracture surface in accordance with Figure 6 of the incident CO_2 bottle.

CT Scanning

CT scanning was performed on the subject pin valve. Annotated images generated from the scanning are shown in Figure 9.

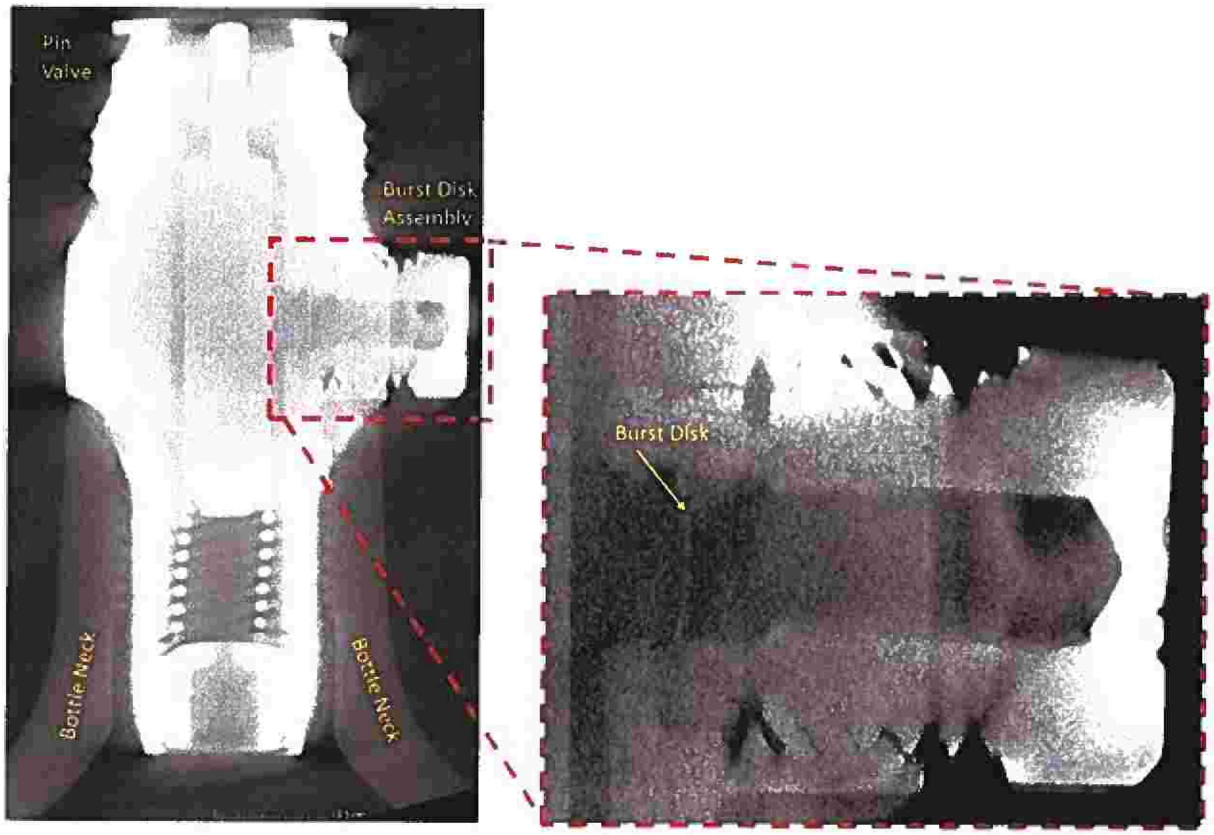


Figure 9. Annotated images generated from the CT scan of the subject CO_2 bottle pin valve (left) and PRD (right).

Figure 9 shows the pin and spring mechanism by which the CO_2 bottle remains sealed until the top pin is depressed sufficiently to open a gap between the moveable pin and the opening in the pin valve. The spring at the bottom of the pin valve (which appears as a series of dots in the cross-sectional image) provides resistance to opening the pin and reseats the pin to seal the bottle when it is not actively being depressed. The bottle neck is also visible in Figure 9, but is darker due to the lower density of the aluminum wall material compared to the brass material of the pin valve.

CT scanning was performed in the area around the PRD without disassembly of the incident bottle. It was determined that the total thickness of the burst disk was approximately 0.15 to

0.17 mm and the deflection of the burst disk was approximately 0.23 to 0.27 mm.[80] The resolution of the CT scan was 0.028 mm.

July 11, 2017

During the July 11, 2017 examination, the PRD from the subject bottle was removed, examined, and tested. Additionally, two exemplar PRDs (Exemplar A and Exemplar B) were provided by defendants. These exemplars were reportedly from a similar vintage as the incident PRD and were also examined and tested. The examination included additional CT scanning, Scanning Electron Microscopy (SEM) with energy dispersive X-ray spectroscopy (EDS), and optical microscopy. The PRD's were hydrostatically pressure tested using an exemplar Tippmann 9 oz. bottle with an installed pressure gauge. Metallography, composition, and hardness testing of aluminum coupons extracted during the testing were also performed.

Optical Microscopy

Optical microscopy was performed on the PRDs and pin valves removed from the subject bottle and the exemplar provided by the defendants. Images taken of the subject PRD and pin valve are shown in Figure 10.

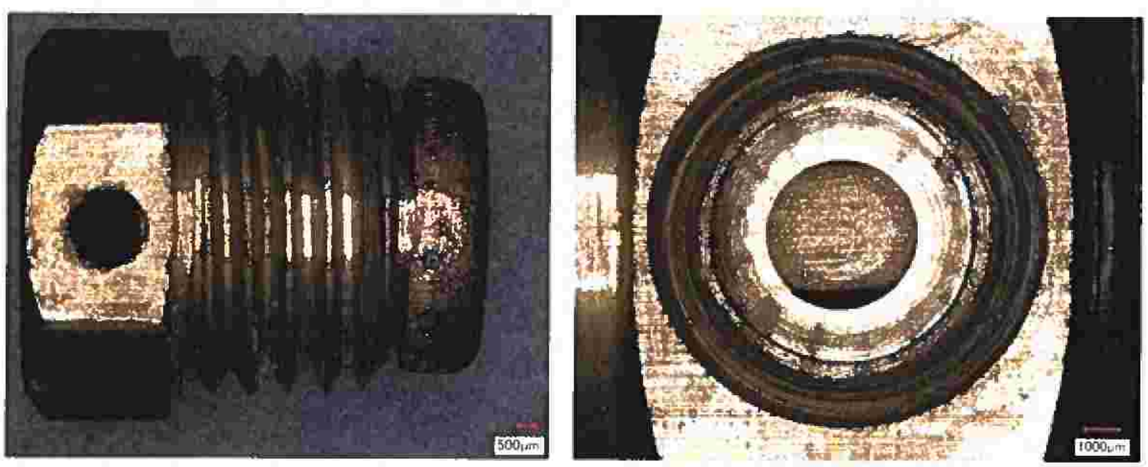


Figure 10. Optical microscopy images taken of the subject PRD (left) and female threads of the pin valve (right) during the July 11, 2017 evidence.

[80] It was later determined that there were two individual burst disks.

SEM and EDS of PRD

SEM and EDS measurements were made on the outside surface of the copper burst disks and copper caps while these remained attached to the PRD. The caps were found to be nearly pure copper with negligible other alloying metals. EDS measurements on the subject PRD cap indicated copper oxide scale and pits containing common salts including sodium chloride and calcium chloride. Results of the pure copper and scale are shown in Figure 11 and results from one of the pits is shown in Figure 12.

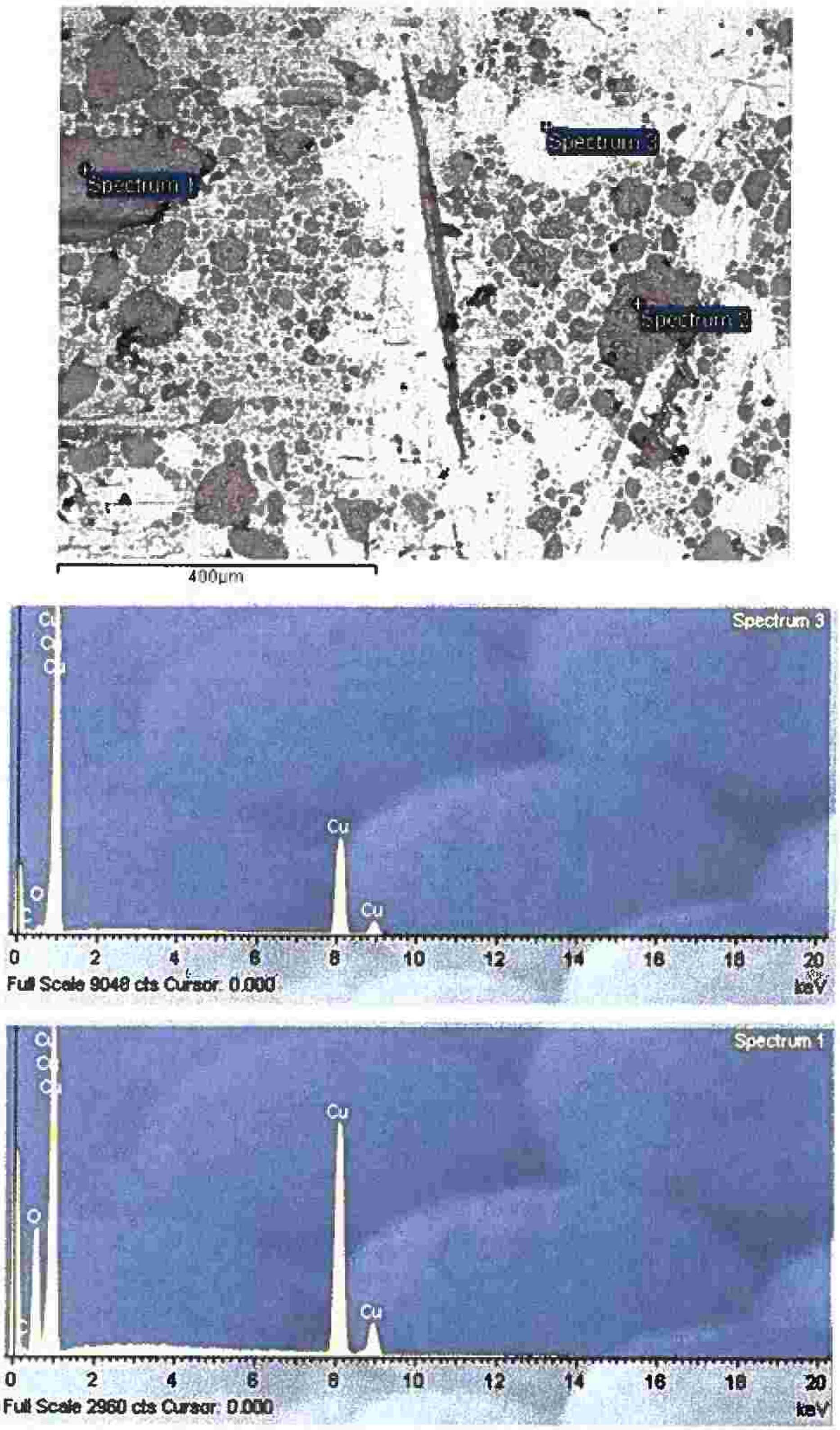


Figure 11. SEM micrograph (top) and corresponding EDS spectrum for point 3 (bottom) for the subject PRD cap.

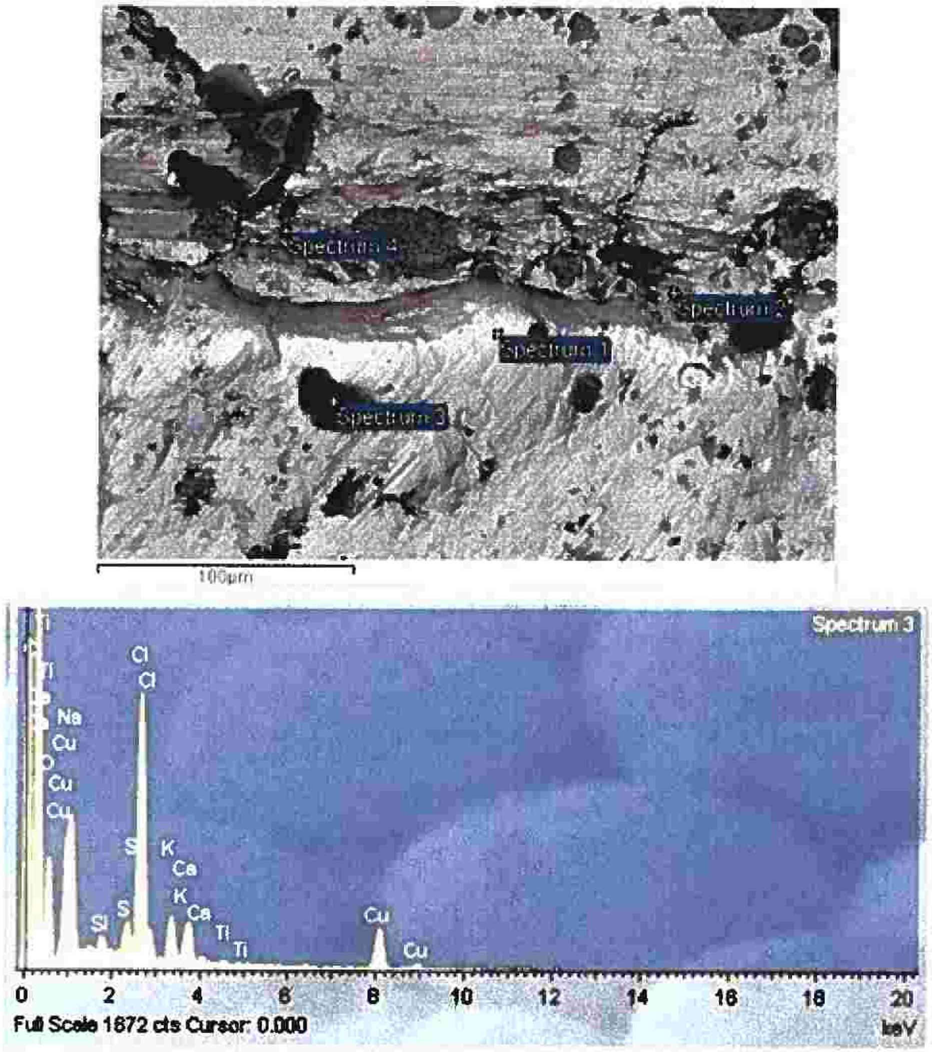


Figure 12. SEM micrograph (top) and corresponding EDS spectrum for point 3 (bottom) for the subject PRD cap.

The burst disk was found to also be made of nearly pure copper with minimal other alloying metals. Some non-copper deposits were also detected on the surface.

Scans of Exemplar A and Exemplar B showed similar high copper content with some non-copper deposits on the surfaces of both the disks and caps.

SEM of Fracture Surface

The fracture surface of the subject bottle was examined with the aid of an optical microscope and a scanning electron microscope. The fractography analysis of the fracture surface indicates that the fracture was ductile in nature with no evidence of brittle fracture, corrosion, or fatigue.

The fracture surface shows evidence of ductile overload indicated by necking (reduction in cross sectional thickness) and ductile cup and cone fracture morphology. Both of which indicate a ductile fracture mechanism (i.e., ductile overload). In addition, there were no observed features, such as damage or defects, that acted as a fracture origin.

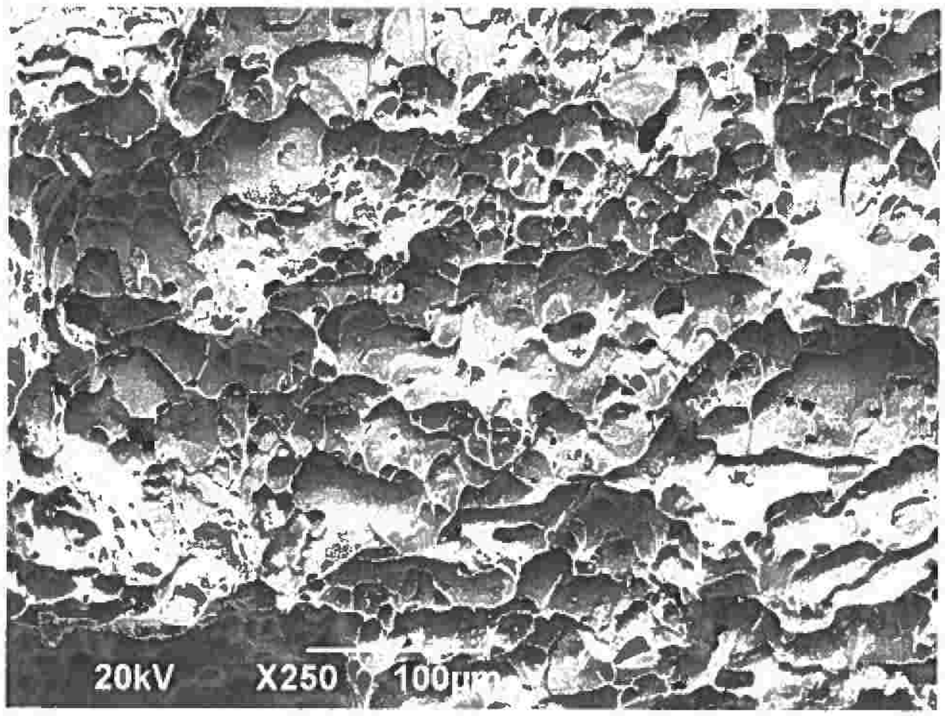


Figure 13. Image from SEM examination of the fracture surface. The morphology of the fracture surface shows distinct cup and cone features indicating ductile fracture.

Hydrostatic Pressure Testing

Hydrostatic pressure testing was performed with a Fluke 700HTP2 hydrostatic pressure tester. An image from the recorded test video can be seen in Figure 14.

Figure 14. Image from test video of the hydrostatic testing of the subject PRD. The pressure gauge and data acquisition system indicate a pressure of approximately 3,300 psi.

Three samples were tested including the subject PRD, exemplar B, and another non-similar exemplar. The results of the testing are shown in Table 5.[81]

Table 5. Hydrostatic pressure testing results

PRD	Maximum Pressure (PSI)	Result
Subject	3,331.5	No burst
Exemplar B	2,665	Burst
Non-similar Exemplar	2,670	Burst
Design	2,700 to 3,000	Burst

CT Scanning

After the PRD was pressure tested, higher resolution CT scans of the subject PRD and pin valve were performed. The scan of the subject PRD indicated it contained two burst disks. A CT image of the two burst disks is shown in Figure 15. The thickness of the disks was found to be

[81] Testing was attempted on exemplar A but leaking around the PRD prevented pressurization and the test was abandoned. The Exemplar B PRD needed to be tightened in the Exemplar B pin valve prior to testing to avoid leakage.

0.07 mm each, consistent with prior measurements. The displacement was found to be 0.23 mm. The resolution of the scans was 0.0075 mm.

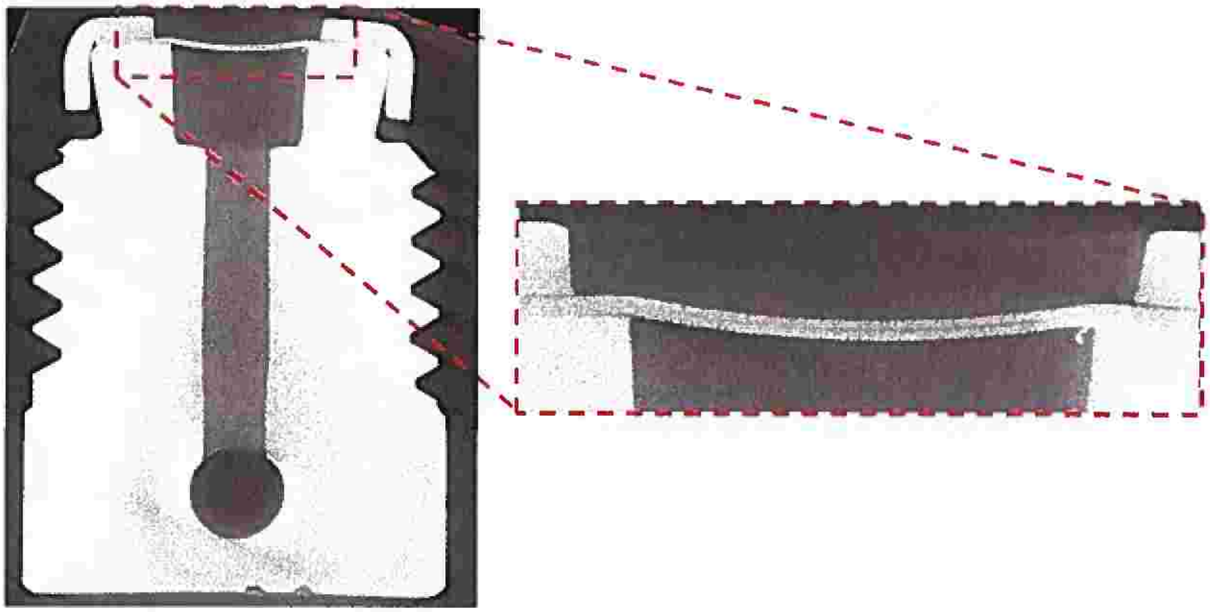


Figure 15. CT images taken July 11, 2017 showing two burst disks in the subject PRD.

Aluminum Composition, Metallography, and Hardness Testing

Chemical analysis of the aluminum coupon was performed by Massachusetts Materials Research, Inc. on August 16, 2017. The results (Table 6) were consistent with UNS A96061. The micro-hardness of the material was found to range from 96 to 121 Vickers. No anomalies were observed in the metallographic analysis.

Table 6. Subject bottle aluminum composition results.

Element	Measured Composition (%)	Specification
Chromium	0.12	0.04 to 0.35
Copper	0.31	0.15 to 0.40
Iron	0.19	0.7 max
Magnesium	0.98	0.8 to 1.2
Manganese	0.03	0.15 max
Silicon	0.73	0.4 to 0.8
Titanium	0.02	0.15 max
Zinc	0.03	0.25 max
Other (Each)	<0.05	0.05 max
Other (Total)	<0.15	0.15 max
Aluminum	Remainder	Remainder

March 29, 2018

During the March 29, 2018 inspection the pin valves and PRDs were removed from the four other bottles owned by Mr. Bates.[82] Additional optical microscopy and CT scanning of the PRDs was performed. The removal of the pin valves and PRDs was performed with a calibrated torque wrench and the torques were recorded.

Valve Removal

The pin valves and PRDs were removed from each of the non-subject bottles own by Mr. Bates. The torques required for the removal of each item is shown in Table 7.

[82] Bottle 3 did not have a PRD installed. Therefore, not PRD was removed.

Table 7. Torque measurements for CO_2 bottle valves.

Bottle	Pin valve torque (in-lbs)	PRD torque (in-lbs)
Bottle #1	373	80.3
Bottle #2	450	34
Bottle #3	385	N/A[83]
Bottle #4	505	53.9

Optical Microscopy

Optical microscopy similar to that taken on July 11, 2017 was performed on the PRDs removed from Bottles 1, 2, and 4. This involved microscopy of the exterior surface of the disk and cap.

CT Scanning

CT scans were performed on the subject PRD that had been pressure tested on July 11, 2017. In these scans, only the section in proximity to the burst disk and cap was imaged. The disk thickness and deflection were extracted from the subject PRD scan as they had from previous CT scans. Figure 16 shows a CT image of the subject disk showing the measurement of deflection measured. The extracted results from all of the scans are shown in Table 8. The deflection of the subject PRD had not increased since its scan on March 17, 2017.

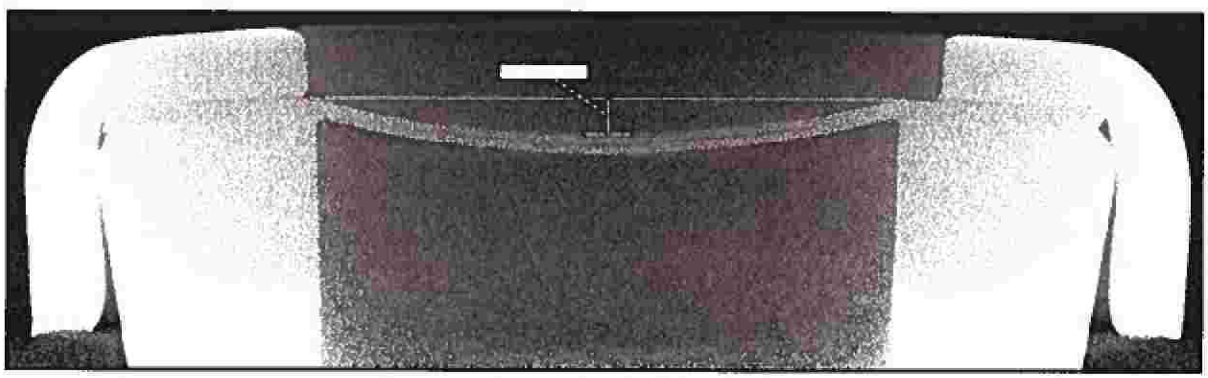


Figure 16. CT image showing measured burst disk deflection. The CT scan resolution is 0.00455 mm.

[83] Bottle #3 did not have a PRD.

Table 8. CT scanning results from follow-up work to March 29, 2018 examination.

PRD	Disk Thickness (mm)	Disk Deflection (mm)
Subject	0.15 (total) 0.07 (per disk)	0.24
Exemplar A	0.07	0.00
Exemplar B	0.07	N/A – Disk burst
Bottle #1	0.07	0.04
Bottle #2	0.12	0.24
Bottle #4	0.08	0.06

May 8, 2018

During the May 8, 2018 inspection, the disks were extracted from five of the six PRDs and examined. For the four PRDs with copper retaining caps, the force required to remove the caps was measured and recorded. Additionally, caliper measurements were made on each of the PRDs to measure the top to bottom length. Each PRD was measured by two individuals at multiple angles and the range was recorded.

Caliper Measurements

The results of the caliper testing are shown in Table 9.

Table 9. Results of caliper measurements from top to bottom of PRDs.

PRD	Caliper Measurement Range (inches)
Subject	0.4950 to 0.4960
Exemplar A	0.4915 to 0.4945
Exemplar B	0.4905 to 0.4945
Bottle #1	0.4930 to 0.4945
Bottle #2	0.5005 to 0.5015
Bottle #3	No PRD installed
Bottle #4	0.4945 to 0.4955

Cap Removal

At the request of the defendants, Exponent built a cap removal tool shown in Figure 17. The tool used two thin sheets of steel that had been cut to allow for a circular opening. The thin steel sheets were slid under the copper cap and used to pull upwards on the cap until it and the copper

disk(s) were removed. The assembly was connected to a force-gauge to measure the force during the process. The pulling was achieved by locking the hex of the PRD into an end-mill drill chuck and mounting the force gauge on the end mill table and then lowering the table.

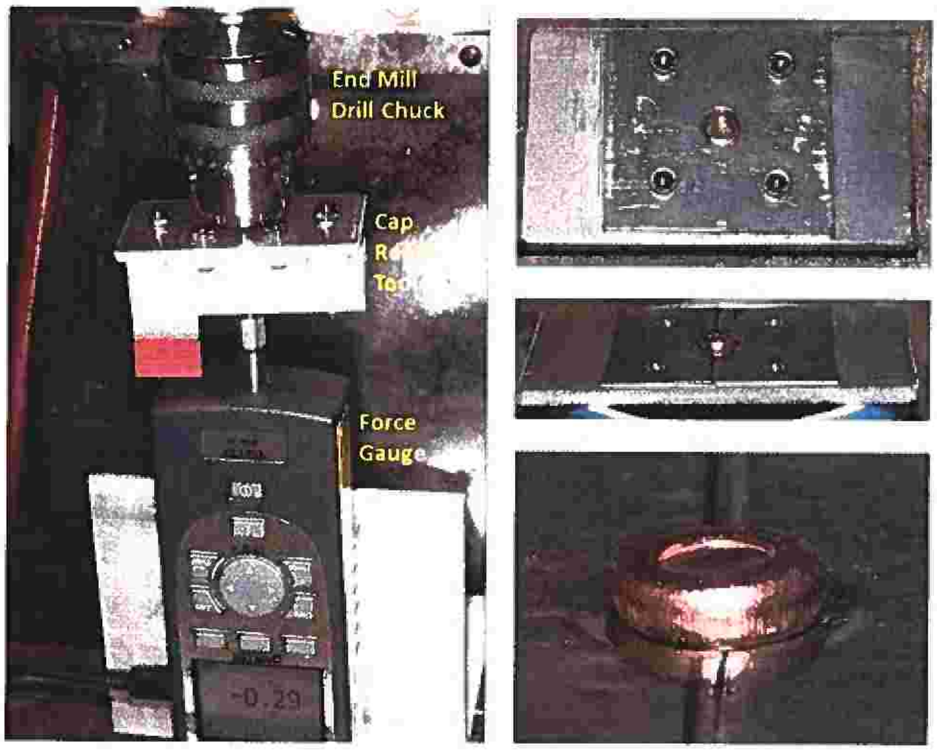


Figure 17. Cap removal tool and system. The left photograph shows the setup for the subject cap removal and force measurement. The right photographs show the in-house built cap removal tool fully assembled (top) and with the top plate removed (center and bottom).

The results of the Cap Removal process are shown in Table 10.

Table 10. Results of cap removal force measurements.

PRD	Maximum Force (lbf)
Subject	151.9
Exemplar B	73.3[84]
Bottle #1	37.5
Bottle #4	44.5

[84] 3.8 lbf was added to the recorded value at the end of the cap separation to account for the initial load

It should be noted that an unknown fraction of the force was related to metal-to-metal contact between the steel sheet and the surface of the brass PRD base. This contact left visible markings on the brass PRD bases and the bottoms of the copper caps.

The copper disk from the non-exemplar PRD in Bottle #2 was also removed by cutting the PRD open. The thickness of the copper disk was measured with a micrometer and found to be consistent with the CT measurement of 0.12 mm. The copper disk had the printed text "3M" on both surfaces.

Optical Microscopy

Optical microscope images were taken of the surfaces of the removed caps and disks that were not previously accessible. Examples of images taken are shown in Figure 18.

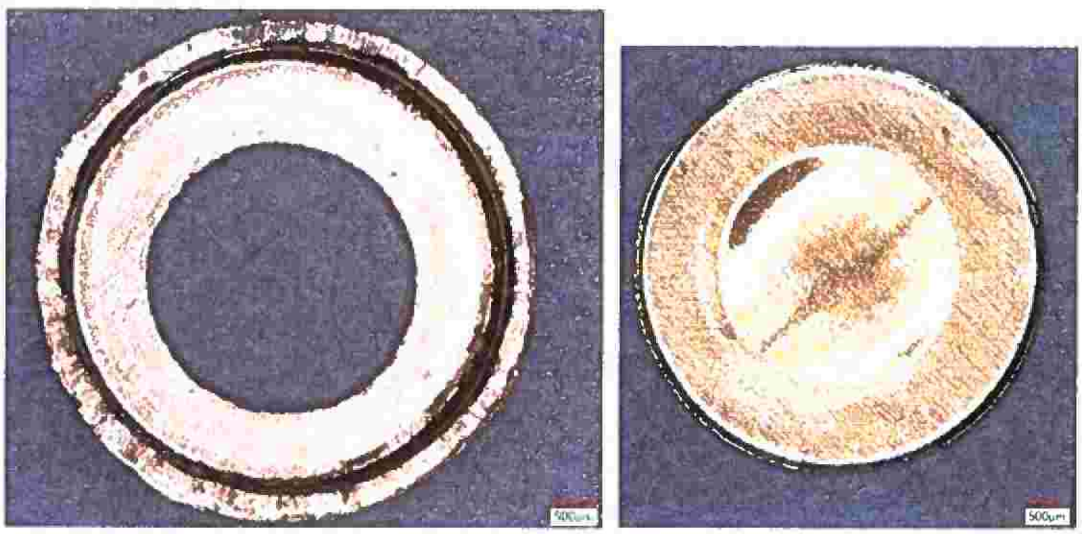


Figure 18. Optical microscope images of the subject PRD copper cap (left) and bottom burst disk (right).

SEM and EDS

SEM and EDS measurements were taken of the bottom of the top burst disk and the top of the bottom burst disk in the subject PRD. The base metal of the burst disks were determined to be nearly pure copper. Some contaminants were identified on both disks.

SEM images of the edge of the disks were taken and are shown in Figure 19.

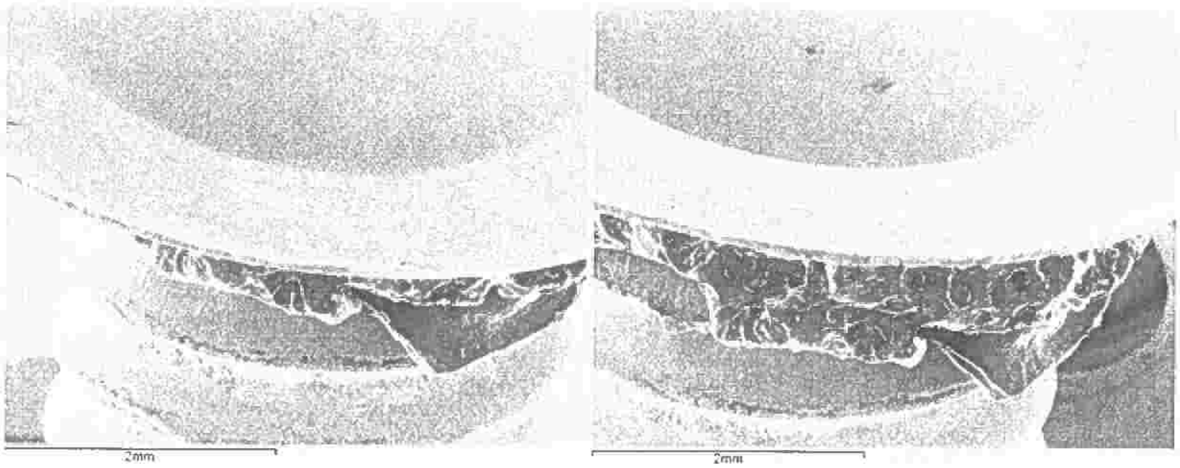


Figure 19. SEM images taken of the sides of the burst disks in the subject PRD. (Left) top disk. (Right) bottom disk.

Testing and Analyses

Pressure of the Bottle Prior to Rupture

The ultimate failure pressure of the failed Tippmann CO_2 bottle that ruptured and killed Mr. Bates was estimated using the equation provided in 49 CFR 178.46 *Specification 3AL seamless aluminum cylinders,* the outer diameter, *D*, and inner diameter, *d*, of the cylinder and the ultimate stress, *S*, of the aluminum 6061. The equation can be used to roughly estimate the ultimate failure pressure (*P*) is shown in Equation 1.

$$P = \frac{S(D^2 - d^2)}{1.3D^2 + 0.4d^2} \qquad \text{Equation 1}$$

Based on the minimum ultimate stress of 45,794 psi[85] of the 6061 aluminum and the minimum wall thickness of the subject bottle (approximately 2.35 mm based on CT analysis shown in Figure 5) a failure pressure of approximately 4,700 psi was calculated.[86] This pressure is above the 3,000 psi maximum burst pressure of the PRD. Had the PRD functioned as intended, the burst disk would have activated and prevented the incident. In the analysis of the fracture surface, there were no indications of external damage that would have reduced the failure pressure.

Gayston also produces a 3AL3000 bottle designed with a service pressure of 3000 psi in contrast to the service pressure of 1,800 psi of the subject bottle.[87] Based on Gayston's testing, the 3AL3000 bottle does not rupture until approximately 8,000 psi.[88] Had the subject bottle been constructed with the same wall thickness as Gayston's 3AL3000 bottle, it would not have

[85] GS0083 – Flattening Test Results on 6061 Aluminum.

[86] Similar failure pressure values can be obtained when using common formulations to estimate the hoop stresses and longitudinal stresses in thin walled cylindrical tanks. Hoop stresses and longitudinal stresses are combined using failure theories to (i.e. Von Mises theory or maximum shear stress theory) to predict the failure pressure of the subject tank.

[87] GS0045 – Certificate of Compliance and Test Report for DOT-3AL3000 aluminum cylinder.

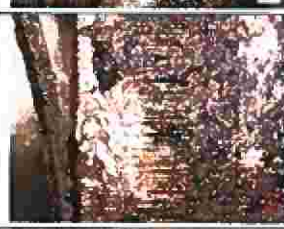
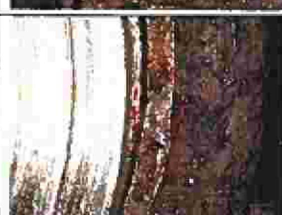
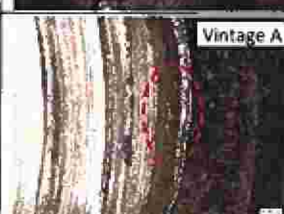
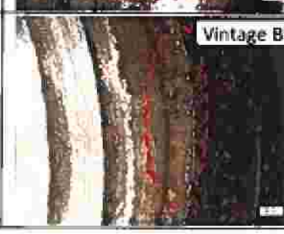
[88] GS0056-GS0058 – Burst Test Results

ruptured prior to the bursting of the PRD at approximately 6,000 psi, and therefore, would have prevented the explosion.[89]

Comparison of Markings, Scratches, and Defects on PRD Caps

A detailed comparisons of the markings, scratches, and other indications on the PRD caps, disks, and brass base was performed using the optical microscopy images taken during the evidence inspections. For each type of marking identified on the subject PRD, similar markings were identified (if present) on the exemplar PRDs and/or the PRDs from Mr. Bates' other CO_2 bottles. Based on the examination, none of the markings on the subject PRD were found to be unique. As discussed, in the elemental analysis section later, however, black copper oxides were found to be more prevalent on the subject PRD. The comparison of markings are shown in Table 11 through Table 13.

Table 11. Comparison of features located on the outer surface of the copper cap.

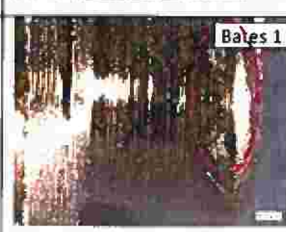
Feature	Subject	Exemplars and other Bates bottles	
Deep scratch-like feature			
Striation-like feature			
Corrosion-like feature			

[89] The relief pressure of two disks is expected to be approximately equal to twice the relief pressure of a single disk.

Table 12. Comparison of features located on the inner surface of the copper cap.

Feature	Subject	Exemplars and other Bates bottles	
Scratches on cap base			
Deformation at inner edge			
Corrosion-like feature			

Table 13. Comparison of features located on the brass base.

Feature	Subject	Exemplars and other Bates bottles	
Deep scratch-like feature			
Striation-like feature			
Corrosion-like feature			

Removal of Exemplar PRD Cap Assemblies

Two caps were removed from purchased PRDs, with similar cap assemblies, using a screwdriver for the purpose of documenting the markings made during this procedure. The damage left by the screwdriver on each cap is shown in Figure 20. The markings are not consistent with any damage found on the subject PRD. Furthermore, had the subject PRD been removed and then replaced, additional marking would have been generated when the cap was re-crimped to the base.

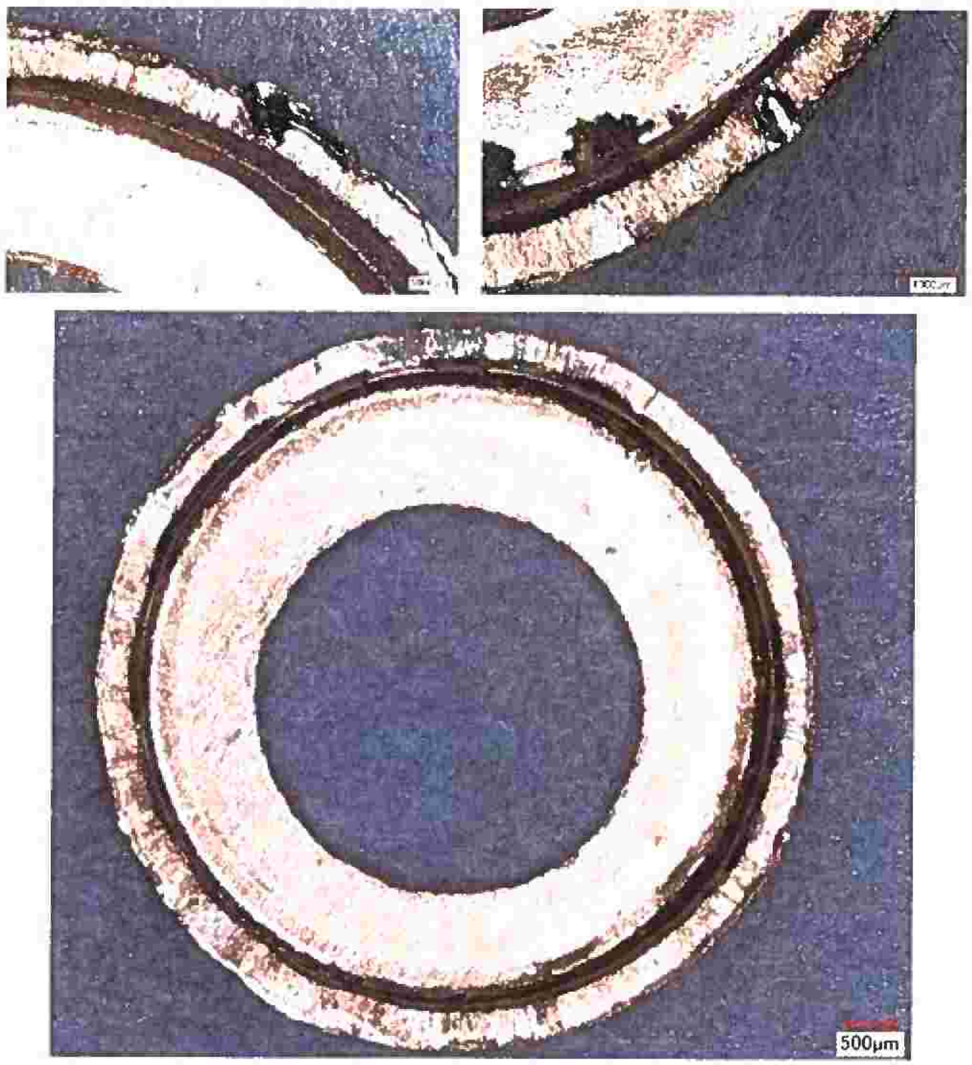


Figure 20. Optical microscope images of markings caused by screwdriver during copper cap removals (top). Optical microscope image of subject cap after removal (bottom).

Installation without re-crimping would not have been possible based on the tightness of the cap on the subject PRD. No common tool (such as pliers) could create a crimp observed on the subject PRD. Both the tightness of the subject cap and the consistency of its markings with other caps that were tested indicate that the crimp was made using a purpose-built crimping machine of the kind used by the manufacturer. Specifically, Aaron Stephens, on behalf of BXD,states in his deposition:[90]

> *Q. Was it possible to remove the copper sleeve and place a new burst disk in the burst disk assembly?*
>
> *A. There is -- I actually have -- I should say that I was told prior to coming to BXD because a tool does not exist to cleanly remove the sleeve and people are not going to have the equipment to recrimp, that that's why it complied to that.*
> *It's not resetable. It's pretty common to have a blow-off valve in these systems. Its redundancies are downstream safety devices. But technically speaking it is not rebuildable because they simply do not have that crimping device, they do not have the tool to remove it.*
> *And the reality is that it's far cheaper -- to go get the tools you can just buy the whole unified burst disk. That's why this standard was put in place is to introduce the standard because prior to the standard it was pretty much the wild west in paintball.*

Elemental Comparison of Burst Disks

Scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDS) were performed on the subject PRD burst disks. As discussed previously, two burst disks were present in the subject PRD. The compositions of the two disks are consistent with one another – they both are composed mainly of copper. Due to the limitations of the SEM/EDS method, the specific alloy of copper cannot be determined.[91]

Specific non-copper contaminants were observed at isolated locations during the SEM/EDS analysis. All of the disks examined were consistent with the copper burst disks used by Joxco in the manufacture of their burst disk assemblies.

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[90] Deposition of Aaron Stephens,Pages 36-37.

[91] According to the 2015 *Handbook of Materials Failure Analysis with Case Studies from the Oil and Gas Industry* by Makhouf et al., "The energy dispersive spectroscopy (EDS) technique is mostly used for qualitative analysis of materials but is capable of providing semi-quantitative results as well."

Causes of the Explosion

Direct Causes

Based on the available evidence and the analysis described in this report, several direct causes for the explosion that killed Mr. Bates were determined:

1. **There was an elevated pressure in the Tippmann CO_2 bottle.** This is a common occurrence that can result from elevated temperatures or liquid fill levels.
2. **A second burst disk was present in the PRD.** The second burst disk prevented operation at the design pressure range of 2,700 to 3,000 psi. Based on our analysis of the available evidence, the addition of the second burst disk occurred during manufacture.
3. **The bottle was incapable of containing the pressure.** The bottle was designed to withstand pressures up to only 4,500 psi (the DOT minimum). Because the double-disk PRD would not rupture until approximately 6,000 psi, the bottle was the weakest component of the bottle and valve assembly.

Contributory Causes

Based on the available evidence and the analysis described in this report, several contributory causes for the explosion that killed Mr. Bates were determined:

1. **The drawings for the PRD were inaccurate.** The design drawings specified a 0.14 mm disk where a 0.07 mm disk was actually being used. Joxco also adjusted the thickness of the copper used for the burst disks on at least one occasion. It is possible that this confusion led to an improper setting or removal of the height gauge that was one of two protection mechanisms against multiple disk PRD fabrications.
2. **Lack of effectiveness of caliper measurements for determining the number of disks in a PRD.** Based on the testing performed during the May 8, 2018 audit, caliper measurements reflected an asymmetry of the components of approximately 0.003 inches (0.08 mm). This variability is greater than or equal to the size of an additional disk.

Therefore, such variability in measurement renders caliper measurements insufficient to guarantee the identification of a single additional 0.07 mm disk.

3. **Lack of manufacturer auditing.** A BXD representative with knowledge of the process did not visit the site for 8 years prior to the incident. Practices present in 2007 may not have been maintained, safety features may have become less effective, or other process changes may have occurred in the intervening years. For example, in Mr. Stephens' review of a 2013 email from the factory, he noticed the frequency of burst disk inspection was not consistent with the CGA requirement.[92]
4. **Insufficient testing documentation to support compliant testing.** Burst pressure testing required by CGA S-1.1 for the PRD was not effectively documented by any of the defendants. The sparse test results that are available indicate that the PRDs were not consistently compliant with ASTM F2030 or CGA S-1.1 due to burst pressures outside the prescribed range. Had better testing and documentation been performed, non-compliant PRD performance may have been identified and corrected.
5. **Lack of an overfill protection system.** Overfill protection systems, which are required for the filling of propane, may have prevented the over-pressurization of the subject bottle. Similarly, overfill indicators were available on other Gayston bottles but were not included on the subject bottle that ruptured. Because no such system was present, the PRD was the sole mitigation device responsible for protecting the user against an explosion.
6. **Lack of a tare weight marking on the Tippmann 9 oz CO_2 bottle.** A tare weight marking as is required for some other pressure-liquefied gases, including propane, would allow the filler to confirm that a bottle is empty prior to resetting the scale to zero and refilling the bottle. Without such a tare weight, the filler can unknowingly overfill the bottle.
7. **Reliance on DOT minimum safety standards.** The safety standards relied upon by Gayston were the standards set forth by the DOT for shipping CO_2. The DOT safety factor for the rupture of the bottle (4,500 psi) compared to the PRD burst pressure (3,000 psi) was less than two. Had a safety factor of two or greater been used, the PRD would

[92] Deposition of Aaron Stephens, pages 65-66.

have actuated prior to the bottle rupture. Gayston manufactures 3AL3000 bottles with a tested burst pressure of around 8,000 psi.[93] Had the subject bottle been made with wall thicknesses equivalent to the 3AL3000 bottle, the explosion would not have occurred.

Alternate Hypotheses Considered but Rejected

Modification by Mr. Bates

The hypothesis that the bottle was modified by Mr. Bates to add the second burst disk was considered. Per NFPA 921 and ASTM E678, the hypothesis was tested against the available data and found to be inconsistent with the available evidence, accepted scientific and logical principles for the following reasons:

1. No markings on the PRD indicated the removal of the cap with flathead screwdriver, knife, or similar tool.
2. No markings on the PRD indicated the cap had been recrimped. Markings similar to those generated by metal pliers on the cap would be expected. Based on the testimony of the BXD consultant Aaron Stephens, tools to cleanly remove the cap and recrimp it are not available to consumers.
3. The cap on the PRD was tightly crimped onto the brass base. This is consistent with how they are intended to be manufactured. Manual crimping with pliers or similar basic tools would not produce a tight crimp that is uniform in appearance.
4. There were no unaccounted burst disks that could have been used by Mr. Bates.
5. None of the other PRDs owned by Mr. Bates showed evidence of tampering or additional burst disks.
6. Mr. Bates' friends and son were not aware of any effort by Mr. Bates to add a second disk.[94]
7. There is no logical reason Mr. Bates would have wanted to add a second burst disk. Had he wanted additional CO_2, he could have used one of the available 20 oz bottles.

[93] GS0045 – Certificate of Compliance and Test Report for DOT-3AL3000 cylinder.

[94] Deposition of Michael Shipley, Page 123; Deposition of Shane Zollo – Page 50; Deposition of Zen Bates – Page 46-47; Deposition of Star Shipley, Page 30.

8. Had Mr. Bates desired to defeat the PRD valve, several easier options existed including replacing the valve with a set screw or putting a glue over the PRD.

For the above reasons, the alternate hypothesis that Mr. Bates added the second burst disk is rejected.

Rupture of the Bottle below 3000 psi

The alternate hypothesis that the bottle ruptured at pressures below 3000 psi was considered. Per NFPA 921 and ASTM E678, the hypothesis was tested against the available data and found to be inconsistent with the available evidence, accepted scientific and logical principles for the following reasons:

1. Based on the wall thickness of the bottle as determined by CT scanning and the aluminum properties determined in testing produced by Gayston, the DOT calculations predict failure pressures in excess of 4,500 psi.
2. CT scanning results show that no change in burst disk deflection occurred after hydrostatically testing the incident PRD at above 3,000 psi. Therefore, the disks were exposed to pressures in excess of 3,000 psi prior to the rupture of the container.

For the above reasons, the alternate hypothesis that Mr. Bates added the second burst disk is rejected.

Appendix A

Materials Reviewed

Materials Reviewed

- Bates-000076: Cherryville Police Department Incident Report NC0360300.
- Depositions and exhibits
  - Holly Beck on January 17, 2018.
  - William Adam Deck on February 14, 2018.
  - David Schmitz on January 17, 2018.
  - Andrew Sheldrick on January 17, 2018.
  - Michael Shipley on October 30, 2017.
  - Star Shipley on February 14, 2018.
  - Douglas Stipanovich on February 16, 2018.
  - Dennis Tippmann on February 9, 2018
  - Shane Zollo on February 14, 2018.
  - Zen Bates on March 30, 2018
  - Gail Selby on April 18, 2018
  - Aaron Stephens on April 18, 2018.
  - William Hearn on May 2, 2018.
- Standards and Regulations
  - 49 CFR §173.115 - Class 2, Divisions 2.1, 2.2, and 2.3 - Definitions.
  - 49 CFR §173.301 - General requirements for shipment of compressed gases and other hazardous materials in cylinders, UN pressure receptacles and spherical pressure vessels.
  - 49 CFR §173.301a - Additional general requirements for shipment of specification cylinders.
  - 49 CFR §173.304 - Filling of cylinders with liquefied compressed gases.
  - 49 CFR §173.304a - Additional requirements for shipment of liquefied compressed gases in specification cylinders.
  - 49 CFR §178.46 - Specification 3AL seamless aluminum cylinders.
  - CGA S-1.1
  - ASTM F2030-11 - Standard Specification for Paintball Cylinder Burst Disk Assemblies

    - ASTM 2553-11 - Standard Specification for Warnings on Refillable CO2 Cylinders Used In the Sport of Paintball
    - ASTM F2856-12 - Standard Practice for Transfilling and Safe Handling of Small CO2 Cylinders for Use in Paintball
    - ASTM E678-07 - Standard Practice for Evaluation of Scientific or Technical Data
    - NFPA 921 (2017) - Guide for Fire and Explosion Investigations
    - NFPA 58 (2014) - Liquefied Petroleum Gas Code
- Scientific Literature
    - Ramirez, Ogle, Carpenter, and Morrison. *Preventing Overpressure Hazards from Trapped Liquids.* Process Safety Progress (Vol.29, No.4), 2010.
- Other Documents
    - Video of burst test in California.mp4
    - Video of burst test in China.avi
- Legal Documents
    - First Amended Complaint, January 12, 2017.
    - Defendant Dick Sporting Goods Inc.'s Answer to Plaintiff's First Amended Complaint, January 25, 2017.
    - Tippmann Sports LLC's Answer and Defenses to Plaintiff's First Amended Complaint and Cross-Claim, January 25, 2017.
    - Tippmann Sports LLC's First Amended Answer and Defenses to Plaintiff's First Amended Complaint and Cross-Claim, February 10, 2017.
    - Separate Answer of Defendant Gayston Corporation to First Amended Complaint, February 18, 2017.
    - Separate Answer of Defendant Gayston Corporation to Cross-Claim by Tippmann Sports, LLC, March 9, 2017.
    - Third-Party Complaint, Gayston, June 13, 2017.
    - Answer to Third-Party Complaint, BXD, July 27, 2017

Appendix B

CV of Dr. Harri Kytomaa

Exponent
Engineering & Scientific Consulting

Harri K. Kytomaa, Ph.D., P.E., CFEI

Group Vice President & Principal Engineer | Thermal Sciences
9 Strathmore Road | Natick, MA 01760
(508) 652-8519 tel | hkytomaa@exponent.com

Professional Profile

Dr. Kytömaa specializes in mechanical engineering and the analysis of thermal and flow processes. He applies his expertise to the investigation and prevention of failures in mechanical systems. He also investigates fires and explosions and their origin and cause. He consults in the utilities, oil and gas, and chemical industries. Dr. Kytömaa's project experience includes consumer products, intellectual property matters, automobiles, aircraft, turbines, compressors, boilers, steam generators, pneumatic and hydraulic systems, instrumentation, nuclear waste management, heat transfer systems, fuel distribution, delivery and storage systems, including LNG facilities.

Dr. Kytömaa has decades of experience in the area of dynamics and thermal hydraulics of piping systems, valves and pipelines. He has developed flow modeling tools for such systems and their components and has applied these to drilling and downhole applications. He pioneered the modeling of the acoustics of drilling fluid piping systems for acoustic telemetry and Measurement-While-Drilling (MWD), which was one of the enabling technologies for directional drilling. Dr. Kytömaa has also developed ultrasonic techniques for both medical and engineering applications, including instrumentation for flow measurement and the characterization of dense suspensions.

Dr. Kytömaa was Assistant Professor and Associate Professor of Mechanical Engineering at the Massachusetts Institute of Technology, where he was head of the Fluid Mechanics Laboratory. He has also held positions as Visiting Professor at the Helsinki University of Technology and at the DOE Pacific Northwest Laboratory in Washington, and served as Lecturer at the Worcester Polytechnic Institute. Dr. Kytömaa consulted for Teleco Oil Field Services, Inc., developing MWD technology and other downhole applications.

Academic Credentials & Professional Honors

Ph.D., Mechanical Engineering, California Institute of Technology (Caltech), 1986

M.S., Mechanical Engineering, California Institute of Technology (Caltech), 1981

B.Sc., Engineering Science, Durham University, England, *First Class with Honors*, 1979

Session Chairman, LNG Plant Safety and Protection: 2014, 2013, 2012 and 2011 AIChE Spring Meetings & 10th, 9th, 8th and 7th Global Congress on Process Safety

Keynote Speaker: AIChE 2014 Spring National Meeting, 14th Topical Conference on Gas Utilization, New Orleans, LA, March 30-April 3, 2014

Liquefied Natural Gas (LNG) installations and equipment, ISO /TC 67/ WG10: Committee Member, 2008-2014

Outstanding Presentation Award, AIChE Spring Meeting, 2013

Excellence Award at the SAE 2006 World Congress & Exhibition

Lewis F. Moody Award for best paper on a subject useful in engineering practice presented to American Society of Mechanical Engineers (ASME), 1993

Henry L. Doherty Professor in Ocean Utilization, 1991-1993

Chairman, Organizing Committee, Engineering Foundation Workshop, Davos, Switzerland, 1993

National Science Foundation Review Panelist, Washington, DC, 1990

National Science Foundation Group Leader, Acoustic Methods Workshop on Visualization of Particulate Two-Phase Flows, Washington, DC, 1990

Diver in the Finnish Navy, rank Able Seaman, Distinguished Service, 1980

Institute of Mechanical Engineers Prize for Outstanding Project Work (United Kingdom), 1979

Licenses and Certifications

Licensed Professional Mechanical Engineer, California, #34290

Licensed Professional Mechanical Engineer, Massachusetts, #48202

Licensed Professional Mechanical Engineer, Louisiana, #PE 0035054

Licensed Professional Mechanical Engineer, Maine, #12370

Licensed Professional Mechanical Engineer, Michigan, #6201057546

Licensed Professional Mechanical Engineer, Washington, #47486

Licensed Professional Mechanical Engineer, New York, #089361

Licensed Professional Mechanical Engineer, Arkansas, #16481

Licensed Professional Mechanical Engineer, Alabama, #35697-E

Licensed Professional Mechanical Engineer, Oklahoma, #28024

Licensed Professional Mechanical Engineer, New Jersey, #24GE05391800

Licensed Professional Mechanical Engineer, Florida, #84434

Licensed Professional Mechanical Engineer, Texas, #129541

Certified Fire and Explosion Investigator (CFEI, Registration No. 13524-6843) in accordance with the National Association of Fire Investigators (NAFI) National Certification Board per NFPA 921 Section 11.6.4

Certified Fire Investigator (CFI certificate No. 20-005) in accordance with the International Association of Arson Investigators (2009-2014)

Fire Investigation 1A Certification accredited by the California State Fire Marshal

Short Course on Aircraft Fire protection/Mishap Investigation, AFP Associates, November 9, 2001

National Waste Operations and Emergency Response Training, 29 CFR 1910.120 (1994-2000)

Asbestos Worker, Certificate No. 97-164-112-102, pursuant to Title II of the Toxic Substance Control Act, 15 USC 2646, 1997

Short Course: Research state-of-the-art in two-phase flows and thermal hydraulics. Faculty: Professors R.T. Lahey Jr, D.A. Drew, O.C. Jones, M.Z. Podowski, A.E. Bergles, Rennselaer Polytechnic Institute, 1988.

Nordic Sportsdiver's Certificate, CMAS International Diving Certificate "2 stars," No 1076

Open Water Certified Scuba Diver, NAUI Certification #: kyto062958harsd

Enriched Air Diver, Nitrox, Max 40% O2 concentration, PADI Diver No. 0604055220

Professional Affiliations

American Society of Mechanical Engineers

American Institute of Chemical Engineers

Society of Fire Protection Engineering

Sigma Xi, The Scientific Research Honor Society

National Fire Protection Association

Languages

Finnish

French

Patents

Hydrogen generator, US 9705145 B2 (Kmetich TJ, Zsigo GA, Mick AR, Kytömaa HK), 2017

Publications

Morse T, Cundy M, Kytomaa H. Vehicle fires resulting from hot surface ignition of grass and leaves. SAE Technical Paper 2017-01-1354, 2017, doi 10.4271/2017-01-1354.

Ibarreta AF, Hart RJ, Ponchaut NF, Morrison DT, Kytömaa HK. How does concrete affect evaporation of cryogenic liquids: evaluating liquefied natural gas plant safety. ASME Journal of Risk and Uncertainty in Engineering Systems, Part B 2(1), 2015.

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Kytömaa HK, Morrison DR. A moving target. LNG Industry Magazine, November/December 2013; 57-62.Morse TL, Kytömaa HK. The effect of turbulence on the rate of evaporation of LNG on water. Journal of Loss Prevention in the Process Industries 2011; 24:791-797.

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Kytömaa HK, Gavelli F. Studies of LNG spills over water point up need for improvement. Oil Gas Journal; May 9, 2005.

Myers TJ, Kytömaa HK, J. Martin RJ. Fires and explosions in vapor control systems: A lessons learned anthology. Process Safety Progress, 2003, vol. 22, no. 4, pp. 195-199.

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Appendix C

Testimony History and Rates

Expert Testimony of
Harri K. Kytömaa, Ph.D.

Five-Year Testimony History

Name of Case	Type	Docket	Year
Markel Insurance Company as subrogee of Ole and Christy Strigel v Amerigas Propane et al.	Deposition	General Court of Justice, Superior Court Division, State of California 16-CVS-4388	2018
In Re: Chevron Refinery Cases	Deposition	Superior Court of California County of Contra Vista C12-01841	2018
Alifax Holding SPA and Sire Analytical Systems SRL v Alcor Scientific Inc. and Francesco A. Frappa	Deposition	United District Court of Rhode Island C.A. No. 14-440-S	2017
Pacific Indemnity Company v Omega Flex, Inc.	Deposition	United States District Court for the District Maine C.A. No. 2:17-CV-00170-JDL	2017
Daniel Fassett and Leslie Fassett v Sears Holding et al	Deposition	United States district Court for the Middle District of Pennsylvania Case 4:15-cv-00941-MWB	2017
Shannon Cheney v Stephen Willson et al	Deposition	Circuit Court of the 15th Judicial Court in an for Palm Beach County Florida Civil Division Case No. 50-2013-CA-007140-MB	2017
State Farm Fire and Casualty as Subrogee of Michael and Holly Crockett v Omega Flex, Inc.	Deposition	United States District Court for the Eastern District of Arkansas Little Rock Division, Civil Action No 4:16-cv-00387-JLH	2017
Quentin Ravizza v Paccar, Inc. et al	Deposition	Circuit Court of Cook County Illinois Case No 2013L10907	2017
Olympus Insurance Company a/s/o Gary and Elizabeth Adams v Omega Flex and Gas Plumbing Services, Inc.	Deposition	Circuit Court of the Eighteenth Judicial Circuit in and for Seminole County, Florida Case No. 014-CA-000808-10-W	2017
Travelers Home and Marine Insurance Company, a/s/o Gerard Graci v Omega Flex, Inc.	Deposition	United States District Court District of Connecticut Civil Action No.: 3:15-cv-00513	2017
Paul Brownlee, Fred Steele and Arutyn Karabadzhakyan v Monsanto Company, et al.	Trial	Superior Court of the State of California for the Country of Los Angeles Case No. BC497582	2016

Name of Case	Type	Docket	Year
Southern California Edison Company and Edison Material Supply LLC v Mitsubishi Nuclear Energy Systems, Inc. and Mitsubishi Heavy Industries, LTD.	Deposition and Trial	International Chamber of Commerce International Court of Arbitration Case No. 19784/AGF/RD	2016
Roslyn Dauber, et al. v Monsanto Company et al.	Trial	Superior Court of the State of California for the County of Los Angeles Case No.BC483342	2016
USAA Casualty Insurance Company as subrogee of Christopher Callisto v Bryan Short d/b/a Legacy Homes and Omega Flex, Inc.	Deposition	Circuit Court of the State of Missouri Eleventh Judicial Court St. Charles County Case No. 14L6-CC0065	2016
Softub, Inc., v Mundial, Inc.	Trial	United States District Court for the District of Massachusetts C.A. No. 1:12-cv-10619	2015
Jerry and Terry Miller v Johnstone Supply, Inc. And Omega Flex, Inc.	Deposition	United States District Court for the District of Arkansas C.A. No. CV-14-3007	2015
Jacqueline Smith, Virginia Pierce, and Mark Rametta v Monsanto Co., Solutia, Inc., Pharmacia Corp., Pfizer, Inc., Southern California Gas Co., and Does 1-350, Inclusive	Depositions and Trial	Superior Court of the State of California for the County of Los Angeles Case No.BC459771 (lead case)	2015
Edward Colella et al. v Monsanto Co., et al.	Depositions and Trial	Missouri Circuit Court Twenty-First Judicial Circuit St. Louis County Cause No.: 09SL-CC01972-01 10SL-CC03437-01 10SL-CC03428-01	2015 & 2016
Julia Smith, et al. v Monsanto Co., et al.	Depositions and Trial	Circuit Court of the County of St. Louis Twenty-First Judicial Circuit Case No. 10SL-CC03822-01	2015 & 2016
Parker Petit and Ironshore Specialty Insurance Company a/s/o Parker Petit, and The American Insurance Company a/s/o Parker Petit v OmegaFlex, Inc.	Deposition	United States District Court for the Northern District of Florida Panama City Division C.A. No.: 3:13cv00618/MCR/EMT	2015
Todd Steidley and Kelli Steidley v Omega Flex, Inc. and Collins Plumbing, LLC	Deposition	District Court of Rogers County State of Oklahoma Case No.: CJ-2013-592	2015

Name of Case	Type	Docket	Year
Fontem Ventures B.V., a Netherlands company; and Fontem Holdings 1 B.V., a Netherlands company v Logic Technology Development LLC, a Florida limited liability company, and DOES 1-5, Inclusive	Deposition	United States District Court Central District of California Case No. CV14-1654 GW (MRWx)	2015
Harodite Industries, Inc. v Warren Electric Corporation	Deposition	State of Rhode Island and Providence Plantations Providence, SC. Superior Court C.A. No.: PC2011-3860	2015
State Farm Florida Insurance Company Harry M. Fuqua v Omega Flex, Inc.	Deposition	United States District Court Northern District of Florida Panama City Division Civil File Action No. 5:14-CV-00295-RS-GRJ	2015
I-Flow LLC, et al v Progressive Medical, Inc.	Trial	United States District Court for The Central District of California Southern Division Case No: SACV12-01064 AG	2014
Linda Hartough and James Floyd v Omega Flex, Inc., Pickney Brothers, Inc., et al	Deposition	State of South Carolina County of Beaufort C.A. No: 2011-CP-07-0550	2014
Ateliers de La Haute-Garonne, F2C2 Systems S.A.S. v Broetje Automation-USA, INC., Brotje-Automation GMBH	Trial	United States District Court for the District of Delaware Case No.: 09-CV-598-JJF	2014
Ken Teel, Individually and as representative of the estate of Brennen Chase Teel, Becky Teel, Ross Rushing, Meg Rushing and State Farm as subrogee of Ross and Meg Rushing v Titeflex Corporation, Gastite Division, Turner & Witt Plumbing, Inc., Texas Electric Company, MSC Holdings, Inc., Morrison Supply Company- Lubbock, Inc. et al.	Deposition	In the District Court 72nd Judicial District Lubbock County, Texas No. 2012-504105	2014
Jacqueline Smith, Virginia Pierce and Mark Rametta v Monsanto Co., Solutia, Inc., Pharmacia Corp., Pfizer, Inc., Southern California Gas Co., and Does 1-350, Inclusive	2nd Deposition & Trial	Superior Court of the State of California For the County of Los Angeles. Superior Court Case No. BC459771	2014
Rebecca Rowland, et al. v KZP Enterprises, LLC et al.	Deposition	In the District Court 166th Judicial District Bexar County, Texas No. 2012-CI-10182	2014
Olympus Insurance Company as Subrogee of Michael and Diane Pikos v Omega Flex, Inc. and Amerigas Partners, L.P. d/b/a Heritage Propane	Deposition	United States District Court Middle District of Florida Tampa Division Case No. 8:13-CV-001232-T-23MAP	2014

Name of Case	Type	Docket	Year
Luv N' Care, LTD v Jackel International Limited	Trial	State of Louisiana Parish of Ouachita. 4th Judicial District Court Civ. No.: 10-1891-CV4	2013
Jacqueline Smith, Virginia Pierce and Mark Rametta v Monsanto Co, Solutia Inc., Pharmacia Corp., Pfizer Inc., Southern California Gas Co. and Does 1-350 Inclusive	Deposition	Superior Court of the State of California. For the County of Los Angeles Civ. No.: BC459771	2013
Larry Pittman and Linda Pittman v Omega Flex, Inc.	Deposition	United States District Court for the Western District of Oklahoma Case No.: 12-CV-00239-C	2013
Dr. Warren Kluger, Lynn Kluger and Tower Hill Select Insurance Company as subrogee of Dr. Warren Kluger v Excellent Designer Homes of Jacksonville, Inc., JD Vaughn & Sons Plumbing, Inc., Bivins Electric Company, Inc., Heritage Operating, LP, Titan Propane, LLC, Cornerstone Propane LP, Energy Transfer Partners GP, LP. and Omega Flex, Inc.	Deposition	United States District Court Middle District of Florida Jacksonville Division Case No: 3:11-CV-554-J-12 TEM	2013
State Farm Fire and Casualty Company as subrogee of Charles and Maritza Webb v Omega Flex, Inc., Buster Patterson, Inc., Short's Electric, Inc., and Gasworks, LLC	Deposition	General Court of Justice Superior Court Division North Carolina Moore County Case No: 11 CVS 1560	2013
Softub, Inc., v Mundial, Inc.	Deposition	United States District Court for the District of Massachusetts C.A. No. 1:12-cv-10619	2013
American Automobile Insurance Company as assignee of Fred and Adrienne Kostecki v Omega Flex, Inc.	Trial	United States District Court for the Eastern District of Missouri Eastern Division Case No: 4:11 cv 00305AGF	2013
Keeley Garcia v Omega Flex, Inc.	Deposition	United States District Court for the Middle District of Alabama Southern Division Case No: 1-13-CV-00015-WKW-WC	2013
I-Flow LLC, et al v Progressive Medical, Inc.	Deposition	United States District Court for The Central District of California Southern Division Case No: SACV12-01064 AG	2013
Lillian Lugo v American Honda Motor Co., Inc.	Deposition	United States District Court for the District of New Jersey C.A. No: 1-12CV-1119 (JEI)(KMW)	2013
American Automobile Insurance Company as assignee of Fred and Adrienne Kostecki v Omega Flex, Inc.	Deposition Trial	Twenty Third Judicial Circuit Jefferson County, Missouri No.: 11JE-CC00022	2012 2013

Compensation

Exponent, Inc. is compensated at $620.00 per hour.

Updated April 2018

Appendix D

Scale Testing Documentation

Exponent

Bates v Tippman

Documentation for Scale Testing

Michael Stern, Ph.D.
Noah Budiansky, Ph.D.
Harri Kytomaa, Ph.D.

QAID - 1506568.000 - 7097

Description of Testing in 7-17-17 Protocol

- 3) Testing of the scale owned by Bates (see Figure 3). The weight reported by the scale will be documented by photographs after hanging weights totally 5 oz, 9 oz, and 13 oz.

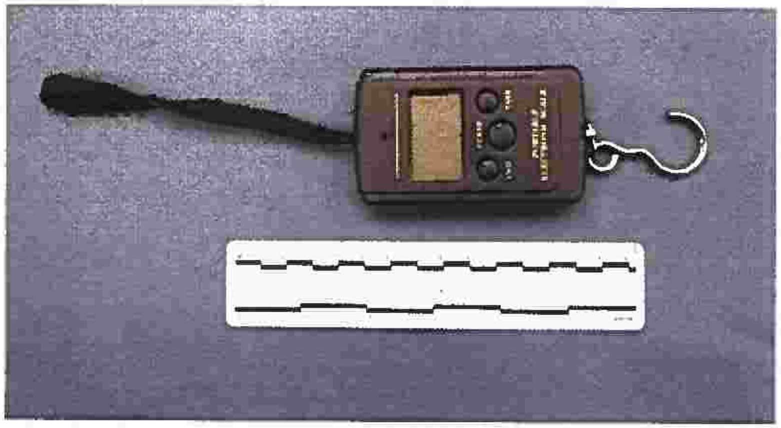
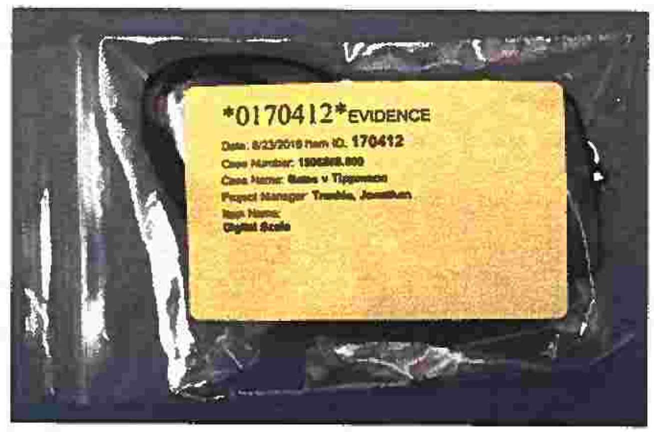


Figure 3 – Scale owned by Bates.



Weights

Labeled mass values were confirmed using calibrated scale
A 1.8 gram plastic bag was used to hold weights during testing

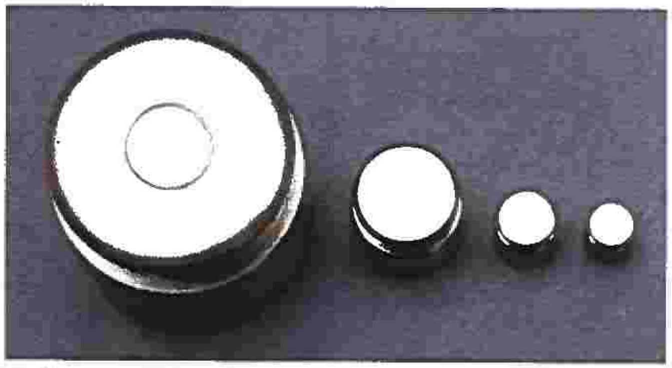
Exponent
Engineering and Scientific Consulting

9 oz (255 gram) test

Trial 1

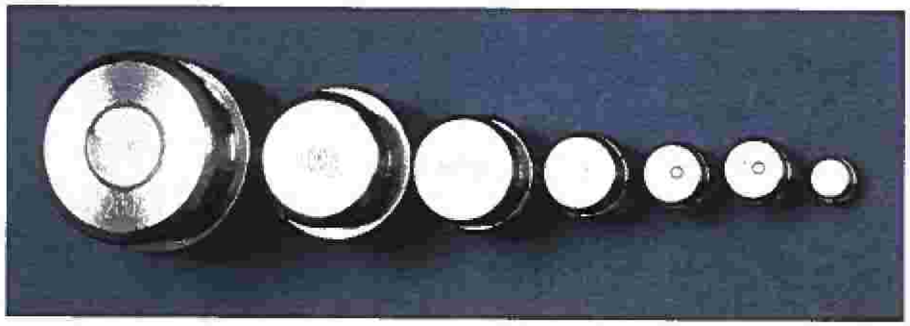
Trial 2

20 oz (565 gram) test



13 oz (392 gram) test

Note: 392 grams = 13.8 oz and is the approximate weight of an empty CO_2 tank



Tare Test

13.8 oz (392 grams) was added to the scale, the scale was zeroed, and then 9 oz (255 grams) was added.

Limitations

- Exponent conducted testing of the incident scale associated with this matter. We have made every effort to accurately and completely investigate all areas of concern identified during our investigation. If new data becomes available or there are perceived omissions or misstatements in this report regarding any aspect of those conditions, we ask that they be brought to our attention as soon as possible so that we have the opportunity to fully address them. The scope of services performed during this testing may not adequately address the needs of other users of this report, and any reuse of this report or its findings is at the sole risk of the user.

Appendix E

Cap Removal Protocol

Exponent
9 Strathmore Road
Natick, MA 01760

PROTOCOL FOR EXAMINATION OF SUBJECT AND EXEMPLAR PRESSURE RELIEF VALVES IN BATES MATTER

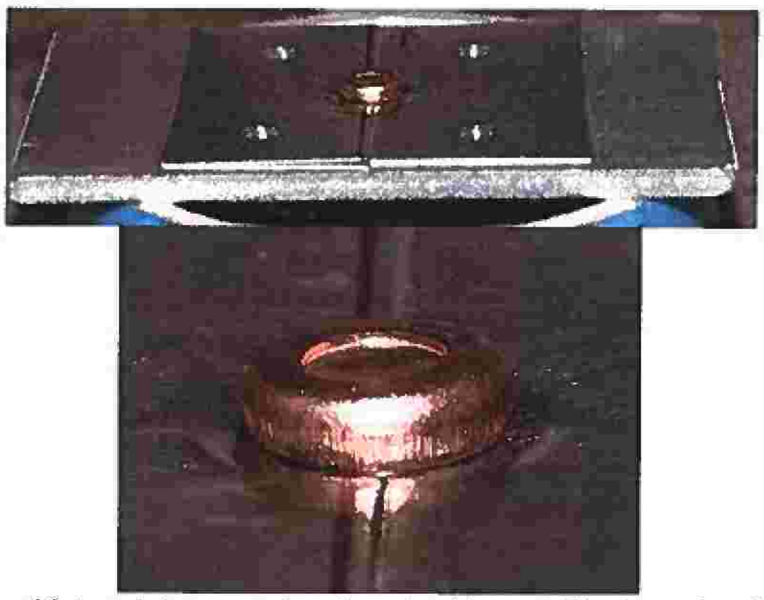
The intent of this protocol is to serve as a guide for examination of multiple exemplar and the subject PRV valves related to the paintball gas cylinder that ruptured at the Bates Residence in February 2015. **The proposed date and location for this examination is May 8, 2018 at 8:00am** at the Natick, MA office of Exponent, Inc. where the subject PRV valve are located. Prior to any examination, this protocol shall be agreed upon by all participating parties, and representatives from these parties that may be present during the examination.

1) The subject and exemplar PRV valves will be unpacked and made available for photographic and dimensional examination using digital cameras, calipers, and the optical microscope.
2) Exponent will provide a cap removal apparatus that places and secures a thin metal lip underneath the majority of the circumference of the PRV copper cap. The hex of the PRV will be affixed into an end mill collet or chuck. An aluminum plate bolted to the metal lip will be affixed to the moveable end mill table. At the request of the defendants, a force gauge will be installed between the aluminum plates and the end mill to record force during the testing. This process is expected to cause scratches, dents, and/or other markings that did not exist prior to the cap removal on both the copper cap and the corresponding section of the brass PRV.
3) Once a test is setup and documented, the end mill table will be slowly lowered to pull the PRV cap from the remainder of the PRV. During the process, the force gauge reading will be monitored.
4) Prior to any testing on the subject PRV, the disassembly of three exemplar PRVs with a fastened cap will be performed.
    a. The process will be video recorded without audio.
5) Once the exemplar caps are removed, they will be made available for documentation by camera and microscope.
6) If the removal is successful with the exemplar PRVs, albeit while creating some markings, the process will be repeated on the subject PRV.

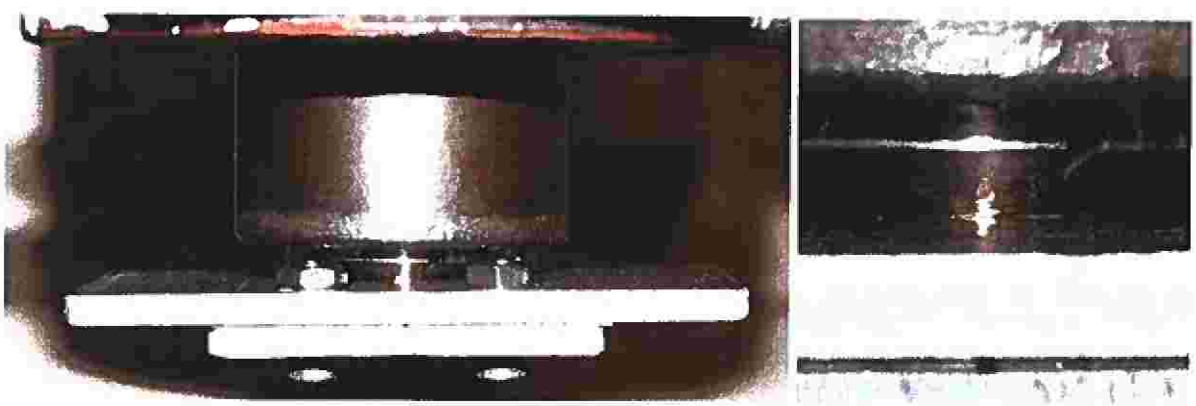
The preceding is a general protocol and is intended to act only as a guide for the examination of the PRVs. During the examination, circumstances may change and/or additional information may become available that requires deviations, additions, and/or omissions from this protocol. Such alterations will occur only with the concurrence of all parties present. All data and images generated during the examination, excluding photographs taken by handheld cameras, will be provided to participating parties. Unless requested by other parties or otherwise noted in specific steps of this protocol, the inspection will not be videotaped.

Exponent
9 Strathmore Road
Natick, MA 01760

Cap removal setup with online purchased PRV installed.



Cap removal setup with top plate removed to show the thin metal lips located underneath the cap.



Cap removal setup installed with PRV hex affixed in end mill collet